PIBS 4082e.

Algoma Slag Dump (St. Marys River) Nearshore Sediment Quality and Contaminant Bioavailability Study

April 2000

Ontario

Ministry of the Environment

Algoma Slag Dump (St. Marys River) Nearshore Sediment Quality and Contaminant Bioavailability Study

Prepared by:
P. B. Kauss
Water Monitoring Section
Environmental Monitoring and Reporting Branch
Ontario Ministry of the Environment
125 Resources Road
Etobicoke, Ontario M9P 3V6

April 2000

Cette publication technique
n'est disponible qu'en anglais.

Printed on 50% recycled paper
including 10% post-consumer fibre

ISBN 0-7794-0221-9

PIBS 4082E

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EXECUTIVE SUMMARY

The Algoma Slag Dump is an approximately 400 hectare Algoma Steel disposal site located above the St. Marys Falls, at Sault Ste. Marie, Ontario, partially on land reclaimed from the river. During August 16th - September 8th, 1989, the Ontario Ministry of the Environment (OMOE) conducted a sediment contamination and biological monitoring assessment of the Algoma Slag Dump nearshore. This study was a follow-up to sediment contamination and landfill leachate problems identified by previous Ministry studies in 1984 through 1987. Leachate infiltration from the dump to the river was identified in 1988.

The 1989 study involved the collection of sediment samples at 16 locations along the dump shoreline to determine sediment quality; an additional upstream station in Point aux Pins Bay served as upstream control. The samples were analyzed for persistent contaminants, including arsenic, cyanide, heavy metals and polycyclic aromatic hydrocarbons (PAHs). Also, unionid mussels (*Elliptio complanata*) in cages were exposed at these same stations for a period of three weeks to determine the biological availability of these inorganic and organic contaminants to aquatic organisms.

Sediments at many of the locations around the dump shoreline contained elevated concentrations of organic carbon, arsenic, cyanide, several heavy metals and PAHs. Concentrations of most contaminants were generally higher at stations located along the eastern half of the shoreline of the dump (i.e., closer to the Algoma Slip). Arsenic, cadmium, chromium, copper, iron, lead, manganese, nickel, zinc and total organic carbon concentrations exceeded the respective Provincial Sediment Quality Guideline (PSQG) Lowest Effect Levels (LELs) at the majority of stations sampled. Arsenic, iron, manganese, zinc and total organic carbon also exceeded their respective PSQG-Severe Effect Levels (SELs) at a some stations. Levels of available cyanide were above the Provincial guideline for open water disposal of dredged material at most stations. Concentrations of Total PAHs as well as of 12 individual PAH compounds also exceeded their respective PSQG-LELs.

Although mean concentrations of arsenic and some metals in the mussels were higher at a few of the stations, these differences were not statistically significant from each other or from pre-exposure concentrations. The spatial pattern of PAH bioavailability and hence, accumulation by the mussels differed from that of metals, with accumulated concentrations being significantly higher at the most easterly stations (i.e., closer to the Algoma Slip). Mussel tissues tended to contain higher concentrations of the more water soluble PAHs (e.g., naphthalene), and very little if any of the lower solubility/higher molecular weight/higher octanol-water partition coefficient compounds (e.g., benzo(g,h,i)-perylene), which were nevertheless present in the sediments. This suggests that the more bioavailable PAHs are those which are more water soluble and present at higher concentrations. Of the 16 PAHs analyzed for, phenanthrene, naphthalene, fluoranthene and pyrene were on average, present at the highest concentrations.

Based on preliminary data from this and other Ministry studies, the Cleanup and Restoration Task Team of the St. Marys River Remedial Action Plan identified and prioritized a number of areas of contaminated sediments and benthic invertebrate community impairment to be considered for remediation and monitoring. As a result of this process, the Algoma Slag Dump was ranked the third-highest in priority, just below the Algoma Slip and Bellevue Marine Park.

ACKNOWLEDGEMENTS

The author is grateful to the following Ministry personnel for their assistance in carrying out this the study: Rick Savage, captain of the survey vessel Monark; crew chief Wendy Page and students Mike Tourney, Lisa Morgan and Shannon Clarke for field measurements and the processing of samples; staff of the Ministry's Laboratory Services Branch Inorganic Trace Contaminants and Trace Organics Sections for chemical analysis of the sediment and mussel tissue samples; Doug Kennedy and Praful Desai for downloading and editing of effluent, river water and sediment quality data; and Elizabeth Timmer for typing of the initial draft manuscript..

This study was partially funded by Environment Canada under the terms of the Canada-Ontario Agreement respecting Great Lakes Water Quality.

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1.0 INTRODUCTION

The Algoma Slag Dump is a large (approximately 400 hectare) area adjacent to the upper St. Marys River that has been used since about 1910 for the disposal of slag from iron and steel making. Over the years, the original shoreline has been changed considerably due to infilling with slag and various wastes (Fig. 1). The disposal of waste materials including waste oil, pickling liquor, Terminal Basins dredged material, coke oven wastes, and the storage of PCBs has ocurred in specific areas of the dump (Fig. 2). The area immediately west of the Algoma Slip is used for the stockpiling of coal and calcium carbonate used in coke production and steel-making, respectively. Dust suppression on the dump roads has employed waste oil containing coal tar. In 1986, an area near the western end of the dump was modified to accommodate docking of vessels for the A.B. McLean sand and gravel operation (Fig 2).

Analysis of water samples from wells drilled on the Slag Dump during 1981-82 detected the presence of a number of contaminants in a groundwater mound located under the site. These included: chloride, sulphate, ammonia, phenol, mercury, solvent extractables, and the polycyclic aromatic hydrocarbons (PAHs) fluoranthene, perylene, benzo(k)fluoranthene, benzo(a)pyrene, benzo(g,h,i)perylene, indeno(1,2,3-cd)pyrene and pyrene (Geocon, 1983)

Previous Ministry studies of sediment quality and benthic invertebrate communities (McKee *et al.*, 1984; Burt *et al.*, 1988) detected elevated concentrations of some metals and of PCBs along the slag dump nearshore. In 1987, surficial sediments collected in the river near the eastern end of the dump (OMOE, unpubl. 1987 data) contained elevated (above upstream background and Provincial open water dredged material disposal guidelines) concentrations of cadmium, iron, lead, magnesium, manganese, zinc, phenol, PAHs, solvent extractables and organic carbon (Appendix A). These concentrations were possibly related to a back-eddy effect (i.e., upstream flow) of the discharge of contaminants from the Algoma Slip, as well as to surface runoff and/or leachate from the site. Also, an oily material on the sediment surface and surface oil slicks were observed in Spring and Bennett Creeks in early 1987. (Bennett Creek discharges to the upper end of the Algoma Slip). Investigation and sediment core sampling in these creeks (see Appendix B, Fig. B-1) detected the presence of a fluid, oily substance, with a creosote-like smell on the surface of the sediments and oil- or tar-saturated deeper layers with a similar odour (Wager *et al.*, 1987). Analysis of samples revealed the presence of numerous unsubstituted and substituted PAHs at elevated (high ppb to low ppm) concentrations in the oily layer and in subsurface core sections (Appendix B). Based on Fourier-transform infrared spectroscopy of some of the samples, the presence of coal tar was confirmed. These findings were followed up by localized clean-up by the industries (OMOE, 1987), involving the vacuum removal of about 3000 gallons of coal tar, and subsequent hydrogeologic studies (Conestoga-Rovers, 1988; Gartner Lee, 1988) and site remediation and the installation of collection systems.

Elevated concentrations of chromium, iron, magnesium, manganese, zinc, certain PAHs and solvent extractables were also found in sediment from the western end of the dump in 1987 (which is far removed from the influence of the Algoma Slip), suggesting losses from the site as

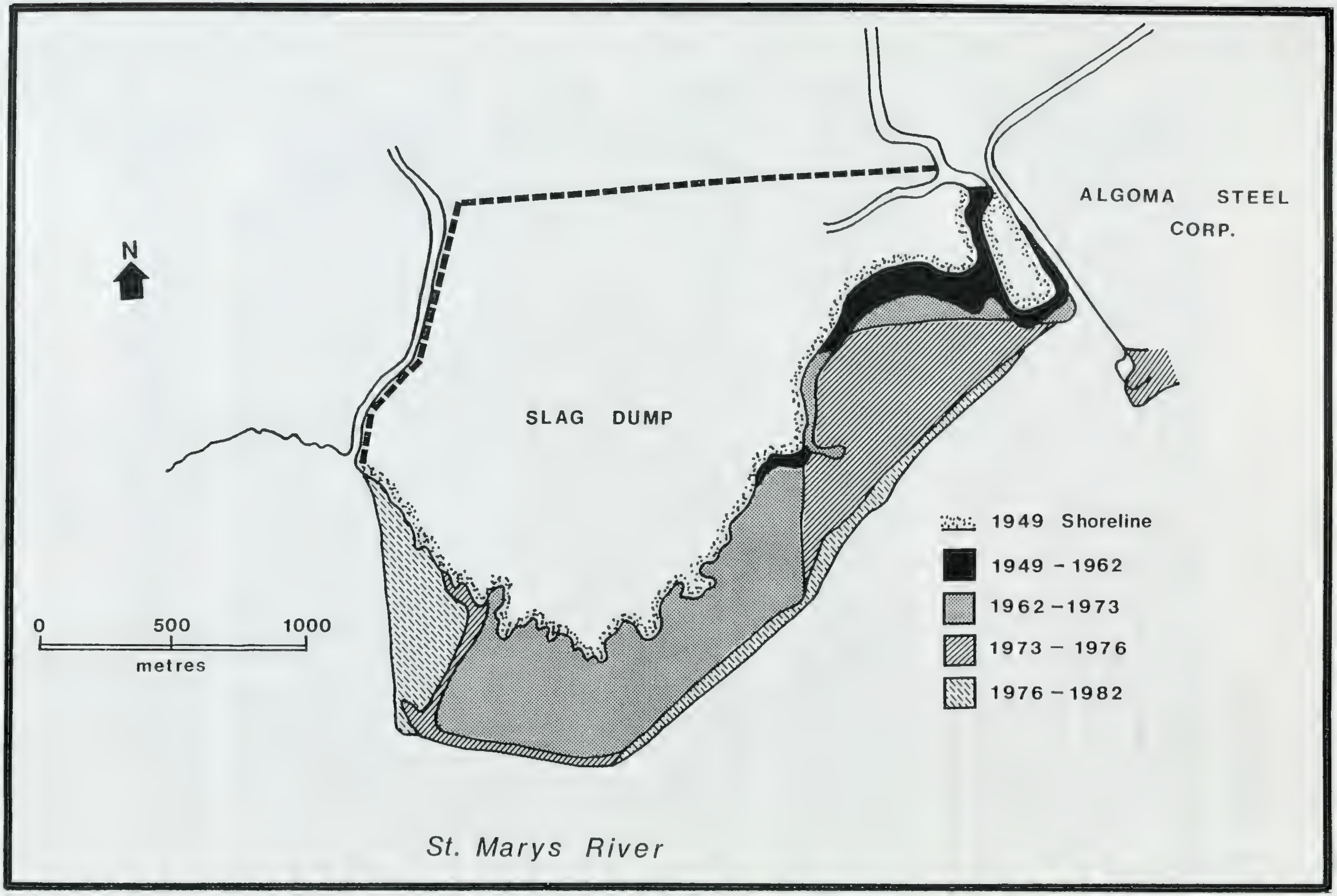

Figure 1. **Historical development of the Algoma Steel Corp. Slag Dump.** (Source: Ontario Ministry of Natural Resources archives).

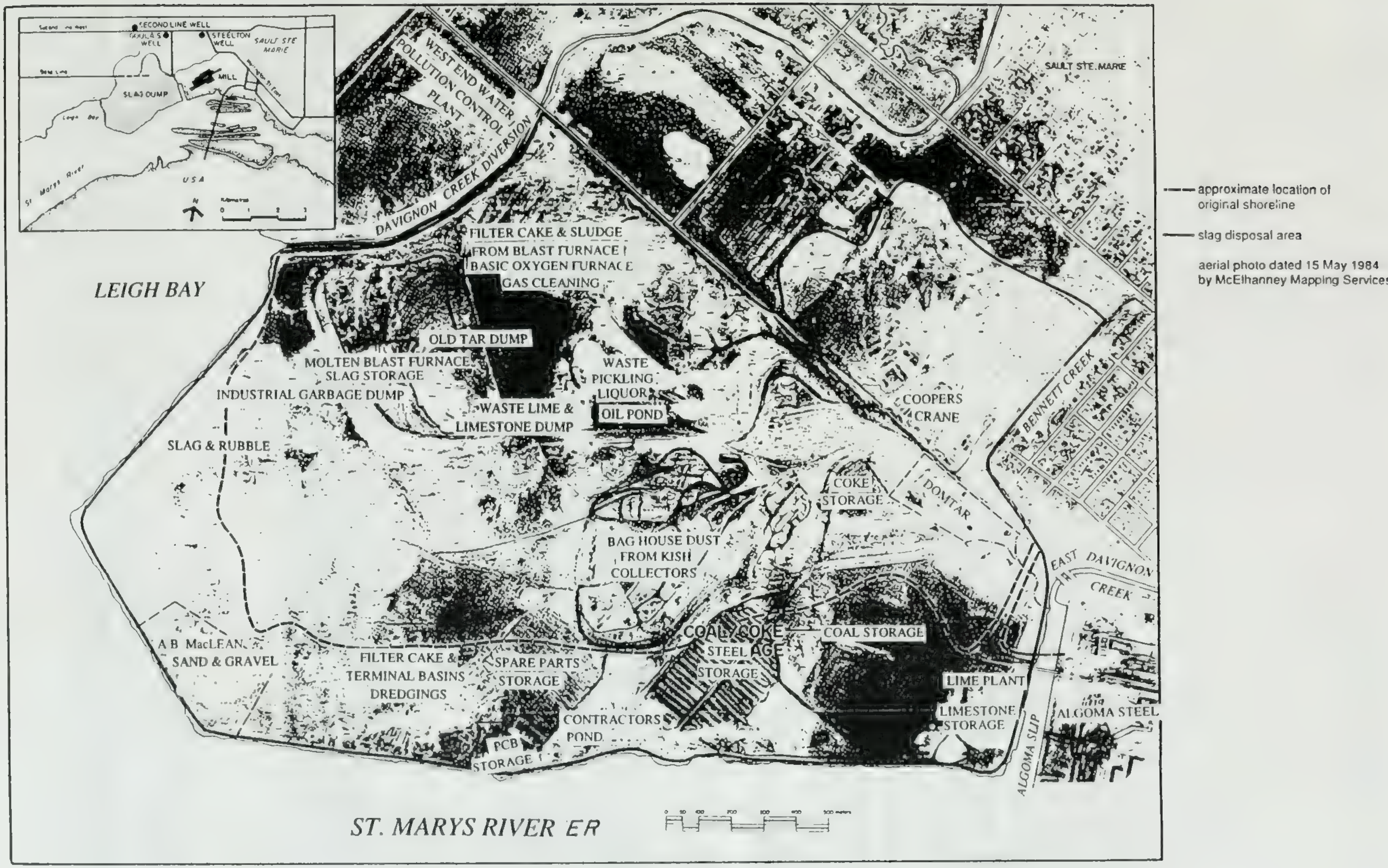

Figure 2. **Waste disposal and storage areas on the Algoma Slag Dump**. (Adapted from Geocon, 1983; Berry-Spark & Tossell, 1990).

the main source. Groundwater seepage had been identified as coming from some areas of riverbed or submerged slag adjacent to the site. However, the main constituents of this seepage were calcium, chloride and sulphate, while no PAHs were detected (Lee & Welch, 1988). Follow-up work was conducted during 1988-89 to determine (among other objectives) groundwater flow pathways, the quality of groundwater migrating off the slag dump, and the contribution of the slag dump inputs to contaminant levels in the St. Marys River and on-site creeks. This indicated that lateral groundwater flow was generally towards the St. Marys River and that discharge of groundwater contaminated by on-site wastes occurs along the St. Marys River shoreline, into the West Davignon Diversion Channel, the ditch along Baseline Road, Bennett Creek and Spring Creek (Fig. 2). Groundwater fluxes into the St. Marys River are upward through the river sediments and the shallow sediment water is chemically similar to shallow groundwater from nearby areas of the Slag Dump. Relative to point (effluent) and non-point (stormwater) source loadings (UGLCCS, 1989), the estimated mass fluxes from the dump site contributed: negligible amounts of the total load of phosphorus, cyanide, phenols, copper, iron and zinc; 3 % of the total chloride load; and 15 % and 32 %, respectively, of the BTX (benzene, toluene, xylenes) and PAH loads. Despite the low percentages, concentrations of numerous contaminants, including phenols, cyanide, cadmium, nickel, zinc, were above PWQOs in shoreline monitoring wells (Berry-Spark & Tossell, 1990).

2.0 OBJECTIVES

The overall objectives of this study were to:

(i) obtain more detailed information on the quality of river sediment adjacent to the Algoma Slag Dump and identify the most contaminated areas; and

(ii) provide information regarding source areas of biologically available contaminants to the St. Marys River.

3.0 METHODS

The 17 sampling locations were in part selected to update information from earlier studies. Also, additional "infill" stations were added to provide better spatial coverage of the dump shoreline. Descriptions and coordinates for the stations shown in Figure 3 are provided in Appendix C, Table C-1.

3.1 Physical Measurements

Water temperature and conductivity were measured at each station at the beginning (August 16th) and end (September 8th) of the three week mussel exposure period, using the appropriate

calibrated meters. Due to technical problems with the meter, dissolved oxygen could only be determined on August 16th. Current speed was also measured on August 16th, with a Marsh-McBirney meter, while the survey vessel was double-anchored.

3.2 Sediment Sampling

Samples of surficial sediment were collected at the 17 stations on August 16, using a clean Shipek dredge of 0.05 m^{-2} sampling area. The stainless steel bucket was hexane (glass-distilled)-rinsed before sampling at each sation. At 13 of the stations, the top 3 cm of sediment from at least three grabs was composited in a clean (hexane-rinsed) Pyrex® glass tray, and thoroughly homogenized with a solvent-rinsed stainless steel spoon. Two additional replicate samples of sediment were collected at two randomly-selected stations to provide data on within-station variability (i.e., local heterogeneity). Also, sufficient sediment was collected at two other randomly-selected stations to permit the analysis of blind duplicate (split) samples and provide information on sample handling/preservation effects and analytical variability.

After a known volume of each sediment homogenate had been weighed and the field (wet) weight recorded, the remaining material was distributed among the prescribed sample jars and preserved as required (OMOE, 1989a)

3.3 Mussel Biomonitoring

Mature *Elliptio complanata* (Lightfoot, 1786; Family Unionidae) specimens were collected from Balsam Lake on August 14, and placed in large (20 litre) food-grade bioassay bags containing lake water for transport to the study area. The mussels were of a restricted size/age class, i.e., long-axis shell length between 6.5 and 7.2 cm; age between 7 and 10 years. In previous Ministry studies, this species accumulated detectable concentrations of persistent environmnetal contaminants such as organochlorines (Kauss & Hamdy, 1985) and PAHs (Kauss & Hamdy, 1991) within a short exposure period (Kauss & Angelow, 1988).

On August 17, the day after sediment sampling, mussels were placed in the river. At each station, 12 clean mussels were placed in a clean (hexane-rinsed) galvanized wire cage (about 30 cm x 36 cm x 10 cm), which was then anchored to the bottom, using a rope tied to a concrete block. In addition, at three of the stations (121, 127 and 197) an extra cage of mussels was suspended at mid-depth using a submerged float.

Cages were recovered on September 8, after three weeks' exposure. Once on board, the mussels were immediately shucked, the soft tissues rinsed with clean water, the fresh (wet) weight recorded, and the soft tissues wrapped in the following materials and frozen on dry ice: for heavy metals - 3 replicates, each in a plastic (food grade) Whirl-Pak bag; for arsenic, cyanide and

Figure 3. Location of sampling and biomonitoring stations in 1989.

mercury - 3 replicates, each in a Whirl-Pak bag; and for PAHs and lipids - 3 replicates, each in hexane-rinsed aluminum foil inside a Whirl-Pak bag. Additional mussels were wrapped as for PAHs and lipids and mainatined in short-term archival storage (at about -15 degrees C), pending receipt of analytical data.

3.4 Analytical Methods

Based on results from earlier Ministry studies, sediment samples were analyzed for a number of parmeters, including physical characteristics, oils and greases, arsenic, cyanide, heavy metals and PAHs. Mussel tissue samples were analyzed for arsenic, selected heavy metals and PAHs. Analysis for these parameters (see Table 1) was performed at the Ministry laboratories in Etobicoke, according to documented procedures (OMOE, 1983; OMOE, 1989b).

Table 1. Sample analytical tests.

Parameter or Scan	Sediment	Mussel
Moisture	√	√
Lipids		√
Particle Size Distribution scan	√	
Residue, Loss on Ignition	√	
Carbon, total Organic	√	
Arsenic	√	√
Cyanide, available & total	√	
Mercury (cold vapour flameless AAS)	√	√
Heavy Metals scan (Cd, Cr, Cu, Fe, Pb, Mg, Mn, Ni, Zn)/(Cd, Cu, Pb, Mg, Mn, Ni,	√	√
Solvent Extractables (Oils & Greases)	√	
Polycyclic Aromatic Hydrocarbons scan (16 compounds)	√	√

3.5 Statistical Analysis

Correlation analysis (Pearson Product-Moment) on sediment and mussel data was performed on transformed (log x+1; arcsin√x for percentages) concentrations of selected parameters; correlations were deemed statistically significant at the 95 % confidence level ($p < 0.05$). Significant differences between contaminant concentrations in mussels were determined using Analysis of Variance (MANOVA) and the Tukey's HSD test at the 95 % confidence level ($p < 0.05$). Pairwise comparison of means was performed using a t-test and a 95 % confidence level.

In statistical calculations, values followed by "<W" were were deemed "not detected" (i.e., not present above the minimum reportable value of the analytical method) and assigned a value of zero, which provides aconservative estimate of the mean. Those values with a "<T" suffix were used as actual values. (The W value is 1.5 standard deviations of the mean for a series of low-level spiked samples; the Method Detection Limit (MDL) is 3 standard deviations. The T value is either 5 or 10 times the W value, depending on the analyte.) For convenience, the W value is

referred to as the Minimum Reportable Value or "MRV" in the following discussion of results. Between the MDL and the T value, there is a 99 % confidence that the value is not a false positive; however, confidence in the actual concentration may not be as high. Above the T value, there is a greater than 99 % confidence that the value is not a false positive and also a high degree of confidence that the analyte concentration is accurate.

4.0 RESULTS AND DISCUSSION

Data for individual replicate or split sediment and mussel samples are provided in Appendix C tables.

4.1 Physical and Chemical Characteristics of Water

At most stations, there was little difference between the surface or the mid-depth measurements of water temperature, dissolved oxygen or conductivity, and the values were within applicable Provincial Water Quality Objectives (PWQOs) for the protection of aquatic life (Table 2).

Table 2. Water quality characteristics during 1989 study. Underlined value in shaded cell does not meet applicable Provincial Water Quality Objective.

Station Number	Metres from shore	Water Depth, m.	Sample Depth, m.	Temperature, °C		Dissolved Oxygen, $mg.l^{-1}$	Conductivity @25 °C, $\mu s.cm^{-1}$		Current Speed, $m.s^{-1}$
				Aug. 16	Sept. 8	Aug. 16	Aug. 16	Sept. 8	Aug. 16
52	500	4.5	4.3	17.4	--	8.9	95	--	0
124	140	1.0	0.8	18.6	--	9.1	96	--	0
205	210	2.0	1.8	18.4	17.9	9.1	97	98	0.05
123	150	3.0	2.8	18.4	17.8	9.8	97	98	0.01
204	50	3.0	2.8	17.7	17.1	9.7	95	99	0.09
203	50	5.0	4.8	17.8	17.0	9.7	95	98	0.08
122	15	5.0	4.8	17.5	16.9	9.5	96	97	0.14
202	20	9.5	9.3	17.3	--	9.3	97	--	0.24
121	40	4.0	3.8	17.7	16.9	9.6	96	97	0.32
121-M	"	"	2.0	--	16.9	--	--	97	--
201	50	4.0	3.8	17.5	16.9	9.8	96	97	0
200	80	3.0	2.8	17.6	16.8	10	96	97	0.09
199	60	8.5	8.3	17.7	--	9.4	97	--	--
198	60	3.0	2.8	18.0	17.0	9.7	97	98	0
197	50	5.0	4.8	17.8	17.0	9.7	97	102	0.09
197-M	"	"	2.5	--	17.0	--	--	102	--
196	50	5.0	4.8	17.6	17.0	<u>0.9</u>	97	100	0
195	70	5.0	4.8	17.3	16.9	9.6	97	97	0
127	70	5.0	4.8	17.7	17.0	9.7	96	97	0
127-M	"	"	2.5	--	17.0	--	--	97	--

NOTES: "--" = no data available; "M" = mid-depth.

Over the three week mussel exposure period, water temperature was relatively constant, differing by less than a degree Celsius. At all but one of the stations, dissolved oxygen was quite high and supportive of a cold water fishery. However, on August 16, dissolved oxygen was 0.9 $mg.l^{-1}$ at Station 196 near the east end of the dump. This is far below the desired PWQOs of 4 $mg.l^{-1}$ for the protection of warm-water fish or the 5 $mg.l^{-1}$ for the protection of cold-water fish (OMOE, 1984; OMOEE, 1994). Conductivity was realtivley constant, only being slightly higher at Stations 204, 203, 197 and 196 on September 8 (Table 2).

There was no measurable current at many of the sampling stations on August 16^{th} (Table 2). However, at Stations 205, 204, 203, 122, 200 and 197, current speed ranged from 0.05 to 0.14 $m.s^{-1}$. These speeds are below the minimum required for the erosion of unconsolidated coarse silt (about 0.15 $m.s^{-1}$). At Stations 202 and 121, the currents of 0.24 and 0.32 $m.s^{-1}$, respectively, were close to or just above the minimum of ~0.30 $m.s^{-1}$ required for the erosion of consolidated coarse silt. (The coarse silt fraction is represented by particles ranging in diameter between 31 and 62 μm.).

4.2 Sediment Quality

4.2.1 Physical Characteristics

Sediment at the Point aux Pins "control" Station 52 was silty-sand in nature, with abundant wood fibres (Table 3). The wood fibres are probably related to use of this area for log booming (OMNR archives). In contrast, sediments adjacent to the Algoma Slag Dump tended to be more sandy (gritty) in nature, at times also including stones, organic ooze, coke granules, iron ore and oil droplets. Laboratory analysis showed that sediments from stations along the dump shoreline consisted mostly of sand and "fines" (i.e., silt and clay - see Fig. 4).

4.2.2 Contaminants

Overall, the mean concentrations of TOC (49 $g.kg^{-1}$), LOI (43 $g.kg^{-1}$) and solvent extractables (567 $mg.kg^{-1}$) for the 16 slag dump stations were below the concentrations at the Point aux Pins Bay control station (66 $g.kg^{-1}$, 140 $g.kg^{-1}$ and 1106 $mg.kg^{-1}$, respectively). In contrast, the average slag dump sediment concentrations of arsenic (7.65 $mg.kg^{-1}$), chromium (34 $mg.kg^{-1}$), available cyanide (0.397 $mg.kg^{-1}$), iron (34220 $mg.kg^{-1}$), lead (35 $mg.kg^{-1}$), magnesium (7642 $mg.kg^{-1}$), manganese (1048 $mg.kg^{-1}$), nickel (14 $mg.kg^{-1}$), zinc (200 $mg.kg^{-1}$) and of each of the 16 polycyclic aromatic hydrocarbon compounds (PAHs) as well as of Total PAHs (23.8 $mg.kg^{-1}$) were considerably above the concentrations in Point aux Pins Bay, by factors ranging from two-fold for nickel to about 130-fold for benzo(a)anthracene (see Tables 3, 5 and 6).

Concentrations of sediment contaminants were compared to the Provincial Aquatic Sediment Quality Guidelines (PSQGs) (Persaud *et al.*, 1993). These guidelines replace the earlier Open Water Disposal Guidelines (OWDGs) (Persaud & Wilkins, 1976) which were used to assess the

Table 3. Sediment physical characteristics, organic carbon and solvent extractables concentrations.

Concentration units as indicated.

Station Number	Visual (Field) Description	Very Coarse Sand 2000-1000 um %	Sand 1000-63 um %	Silt & Clay <63 um %	Moisture %	Field Density g.cm^{-3}	Residue, total loss on Ignition g kg^{-1}	Organic Carbon, total g kg^{-1}	Solvent Extractables mg kg^{-1}
Pointe aux Pins Bay									
52	silty; abundant wood fibre	4.79	62.6	32.6	53	1.36	140	66	1106
Algoma Slag Dump									
124	silty sand; macrophytes	0.08 0 %	86.9 1 %	13.1 3 %	29 2 %	1.79 --	5.0 18 %	5.2 8 %	398 31 %
205	silty sand and clay; some stones	2.15	72.0	25.9	25	1.89	4.0	4.0	222
123	silty sand	2.02	91.6	6.37	23	1.96	5.0	3.0	405
204	organic ooze; macrophytes	13.1 13 %	54.6 1 %	32.2 7 %	52 1 %	1.34 --	53 7 %	28 2 %	497 61 %
203	organic ooze; abundant macrophytes	15.7	51.3	33.1	58	1.25	68	33	274
122	silty sand; reddish surficial layer; oil droplets	3.31	68.5	28.2	34	1.71	32	25	206
202	sand; some stones; coke granules on surface	5.02	92.1	2.88	18	2.04	40	22	264
121	silty sand; rust-coloured lumps	0.34	54.7	45.0	29	1.79	5.0	14	380
201	sandy silt; some oil droplets	0.16	45.5	54.3	31	1.71	12	10	3264
200	sandy silt; rust-coloured lumps; macrophytes	3.19	39.6	57.2	43	1.44	21	14	321
199	sandy ooze; quite oily	0.86 25 %	42.6 9 %	40.5 6 %	38 5 %	1.69 --	46 3 %	71 1 %	251 --
198	sandy ooze; very oily	1.33	60.2	38.5	48	1.47	82	**110**	471
197	sandy ooze; very oily	4.63	54.2	41.1	54	1.34	76	98	322
196	oily ooze; some fine sand	2.20	56.7	41.1	49	1.38	76	**100**	406
195	oily ooze; some fine sand; plant and wood fibres	0.83 70 %	72.4 2 %	26.7 7 %	46 9 %	1.42 --	77 13 %	**120** 8 %	699 97 %
127	sandy ooze; very oily	0.78	79.7	19.5	45	1.41	80	**130**	692
Dump Mean:		3.48	63.9	31.6	39	1.60	43	49	567
PSQG-LEL:		--	--	--	--	--	--	10	--
PSQG-SEL:		--	--	--	--	--	--	100	--
OWDMDG:		--	--	--	--	--	60	--	1500

NOTES: "--" indicates that guideline or CV is not available for this parameter

underlined value in shaded cell exceeds PSQG-LEL or OWDMDG; bolded value exceeds PSQG-SEL

Percentages after concentrations are the Coefficient of Variation. For n = 3, CV = (Std Dev'n./Mean) x 100; or for n = 2, CV = [square root of 2(max.-min./min. + max.) x 100]

"S" after station number = split (same grab) sample; n = 2

"R" after station number = replicate (discrete grab) sample; n = 3

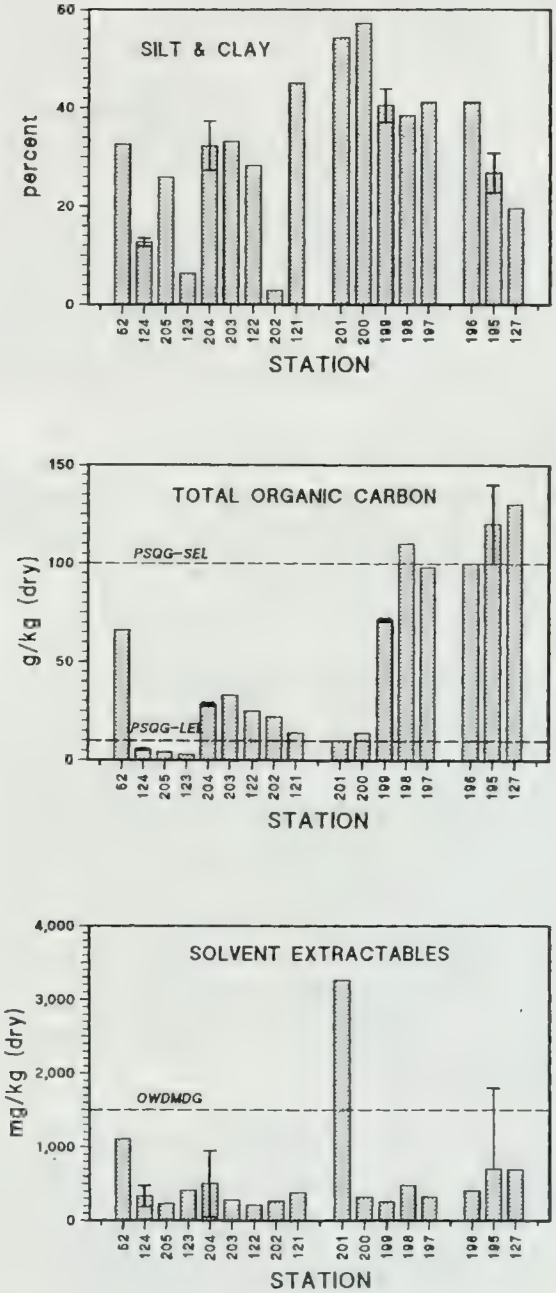

Figure 4. Percent silt and clay, and total organic carbon and solvent extractables concentrations in sediments. Vertical lines on bars represent one standard deviation of replicates (n = 3) or range of split samples (n = 2).

Table 4. **Provincial Sediment Quality Guidelines and their significance** (Persaud *et al.* 1993).

Contaminant Concentration	Sediment Quality	Potential Impact
≤ No Effect Level (NEL)	clean	expect no impact on benthic organisms or biomagnification through the food chain; other water quality and use guidelines will be met
≥ No Effect Level (NEL)	clean to marginally polluted	potential to affect some sensitive water uses
≥ Lowest Effect Level (LEL)	marginally to significantly polluted	will affect sediment use by some (sensitive) benthic organisms
≥ Severe Effect Level (SEL)	grossly polluted	will significantly affect use of sediment by the majority of benthic organisms

suitability of soils and dredged material for open-water disposal. In contrast, the PSQGs are specifically intended to protect aquatic biological resources by setting safe levels for metals, nutrients, and persistent organic compounds. These guidelines are based on three levels of ecotoxic effects: a No-Effect Level (NEL), a Lowest Effect Level (LEL), and a Severe Effect Level (SEL), the significance of which are summarized in Table 4.

Sediments from some of the slag dump stations were "marginally" or "grossly polluted" with respect to the concentrations of total organic carbon (TOC), loss on ignition (LOI), arsenic, heavy metals and various PAH compounds. Such concentrations would have the potential to affect use by the more sensitive sediment-dwelling organisms (marginally polluted) or significantly affect use by the majority of organisms (grossly polluted). Total organic carbon (TOC) exceeded the PSQG-LEL of 10 $g.kg^{-1}$ at the control (Station 52), and at 13 of the 16 stations around the perimeter of the dump. At the most easterly stations, (198, 197, 196, 195, 127), TOC levels exceeded the PSQG-SEL of 100 $g.kg^{-1}$ (Fig. 4; Table 3). Loss on ignition at the latter stations also exceed the old Open Water Dredged Material Disposal Guideline (OWDMDG) of 60 $g.kg^{-1}$ (Table 3). Concentrations of solvent extractables only exceeded the 1500 $mg.kg^{-1}$ OWDMDG at Station 201.

With the exception of mercury (no PSQG exceedences) and magnesium (with no PSQG), concentrations of all inorganics and heavy metals were higher than their respective PSQG-LELs or OWDMDGs at six or more of the stations around the perimeter of the dump (Table 5). Levels at control Station 52 only exceeded the PSQG-LELs for cadmium and copper. The highest concentrations of arsenic, copper, cyanide, iron, lead, nickel and zinc, were found at stations near the eastern end of the slag dump (i.e., Stations 199, 198, 197, 196, 195 and 127), with the peak concentration usually occurring at Station 199. Concentrations of magnesium and manganese were also high at these stations, but along with cadmium, chromium, copper and iron, they were also elevated and above the respective PSQG-LELs at a number of more westerly locations, including Stations 204, 203, 122, 202, 121 and 201 (Table 5). This may be due to

Table 5. Arsenic, cyanide and heavy metals concentrations in sediments.

Station Number	Arsenic	Cadmium	Chromium	Copper	Cyanide available	Iron	Lead	Magnesium,	Manganese	Mercury	Nickel	Zinc
Pointe aux Pins Bay												
52	3.20	**0.87**	14	24	0.022 <T	7400	21	1800	94	0.03 <T	7.1	40
Algoma Slag Dump												
124-S	1.25 6%	0.14 <T 5%	11 0%	5.25 4%	0.040 <T 0%	7350 3%	6.0 0%	1650 4%	125 6%	0.01 <W 0%	5.1 5%	27 0%
205	1.20	0.05 <W	15	7.9	0.020 <T	8500	5.9	2400	120	0.02 <T	7.5	18
123	1.40	0.18 <T	9.7	5.5	0.020 <T	7000	8.3	1400	96	0.01 <W	4.7	16
204-R	3.53 13%	0.72 8%	31 4%	27 4%	0.020 <T 100%	16333 9%	22 22%	4300 8%	253 12%	0.03 <T 33%	15 0%	74 5%
203	4.20	0.66	49	29	0.024 <T	24000	21	6400	**1100**	0.04 <T	18	100
122	5.70	0.30	65	20	0.095	21000	17	16000	**3600**	0.03 <T	10	44
202	1.90	0.05 <W	27	7.4	0.024 <T	22000	9.9	8300	**1500**	0.01 <W	5.2	14
121	3.50	0.23 <T	43	16	0.110 <T	16000	11	4200	**1600**	0.02 <T	8.6	38
201	2.20	0.17 <T	23	13	0.071 <T	13000	13	2800	520	0.01 <W	7.5	29
200	2.70	0.31	23	19	0.110	15000	11	3200	350	0.01 <W	9.7	38
199-S	**39.5** 2%	1.30 11%	73 2%	31.5 2%	1.900 22%	**170000** 0%	155 5%	5050 1%	**3450** 2%	0.09 -	42 3%	**1300** 0%
198	16.0	0.25 <WE	39	28	0.460	**80000**	75	3900	990	0.08	20	360
197	11.0	0.64	40	35	1.000	39000	64	5000	790	0.12	19	330
196	11.0	0.64	37	35	0.300	39000	57	5000	770	0.12	18	310
195-R	8.60 10%	0.46 30%	32 3%	30 2%	0.853 30%	35333 4%	44 5%	4767 1%	743 3%	0.07 29%	16 3%	217 3%
127	8.70	0.32	31	29	1.300	34000	43	5000	760	0.04 <T	16	280
Dump Mean	7.65	0.40	34	21	0.397	34220	35	4960	1048	0.04	14	200
PSQG-LEL	6	0.6	26	16	—	20000	31	--	460	0.2	16	120
PSQG-SEL	33	10	110	110	—	40000	250	--	1100	2.0	75	820
OWDMDG	--	--	--	--	0.100	--	--	--	—	--	--	--

NOTES "--" indicates that guideline or CV is not available for this parameter

Percentages after concentrations are the Coefficient of Variation For n 3, CV = (Std Dev'n /Mean) x 100, or for n = 2, CV = [square root of 2(max -min /min + max) x 100]

"<T" = a measurable trace amount interpret with caution

"<TE" = a measurable trace after extra dilution or concentration caution

"<W" = no measurable response (zero) less than reported value

"<WE" = no measurable response (dilution/concentration. less than reported value

Underlined value in shaded cell exceeds PSQ-LEL Guideline or OWDMD guideline, bolded value exceeds PSQ-SEL Guideline

"S" after station number = split (same grab) sample; n = 2

"R" after station number = replicate (discrete grab) sample, n = 3

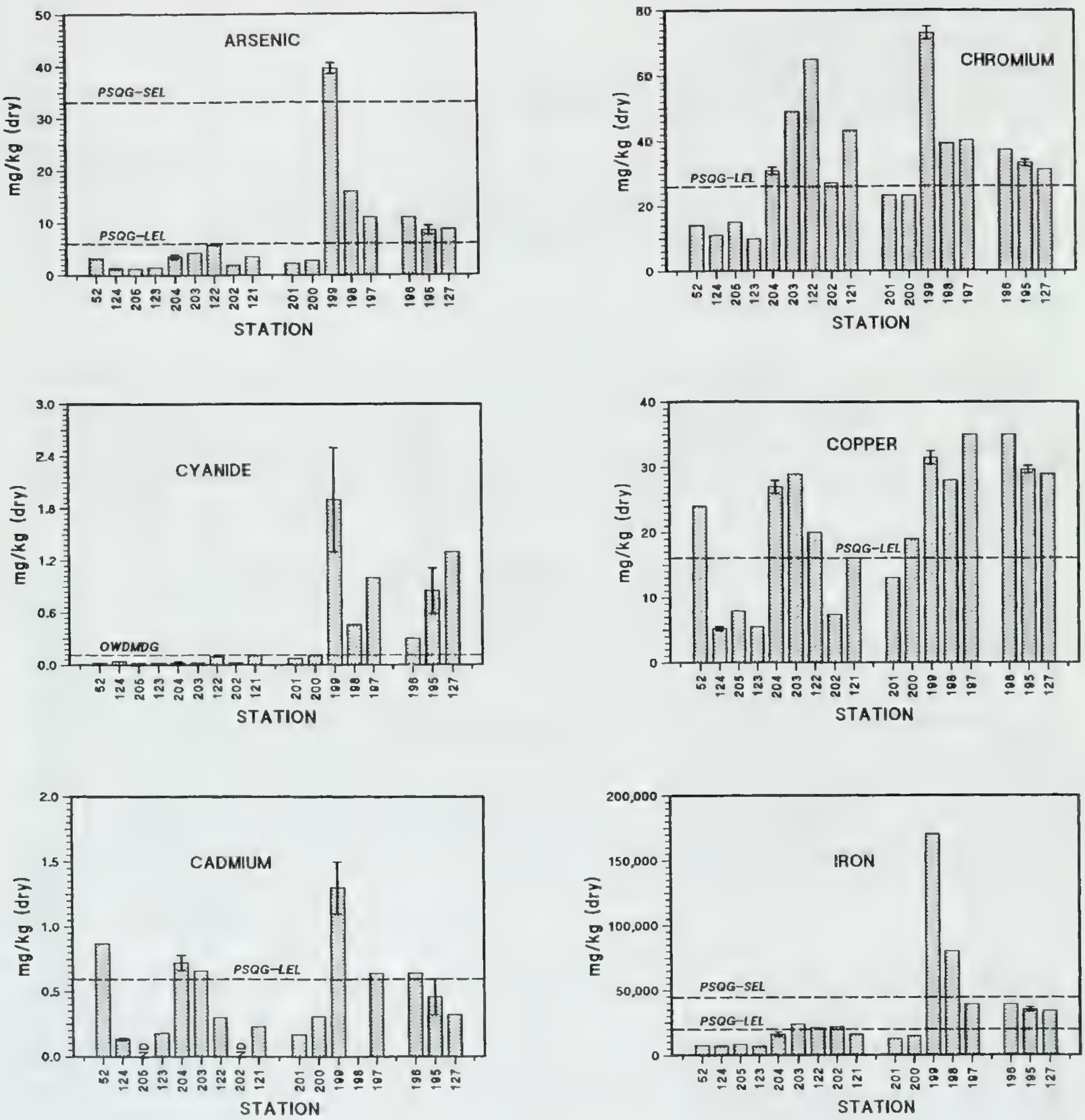

Figure 5. Concentrations of arsenic, cyanide, cadmium, chromium, copper and iron in sediments. Vertical lines on bars represent one standard deviation of replicates (n = 3) or range of split samples (n = 2).

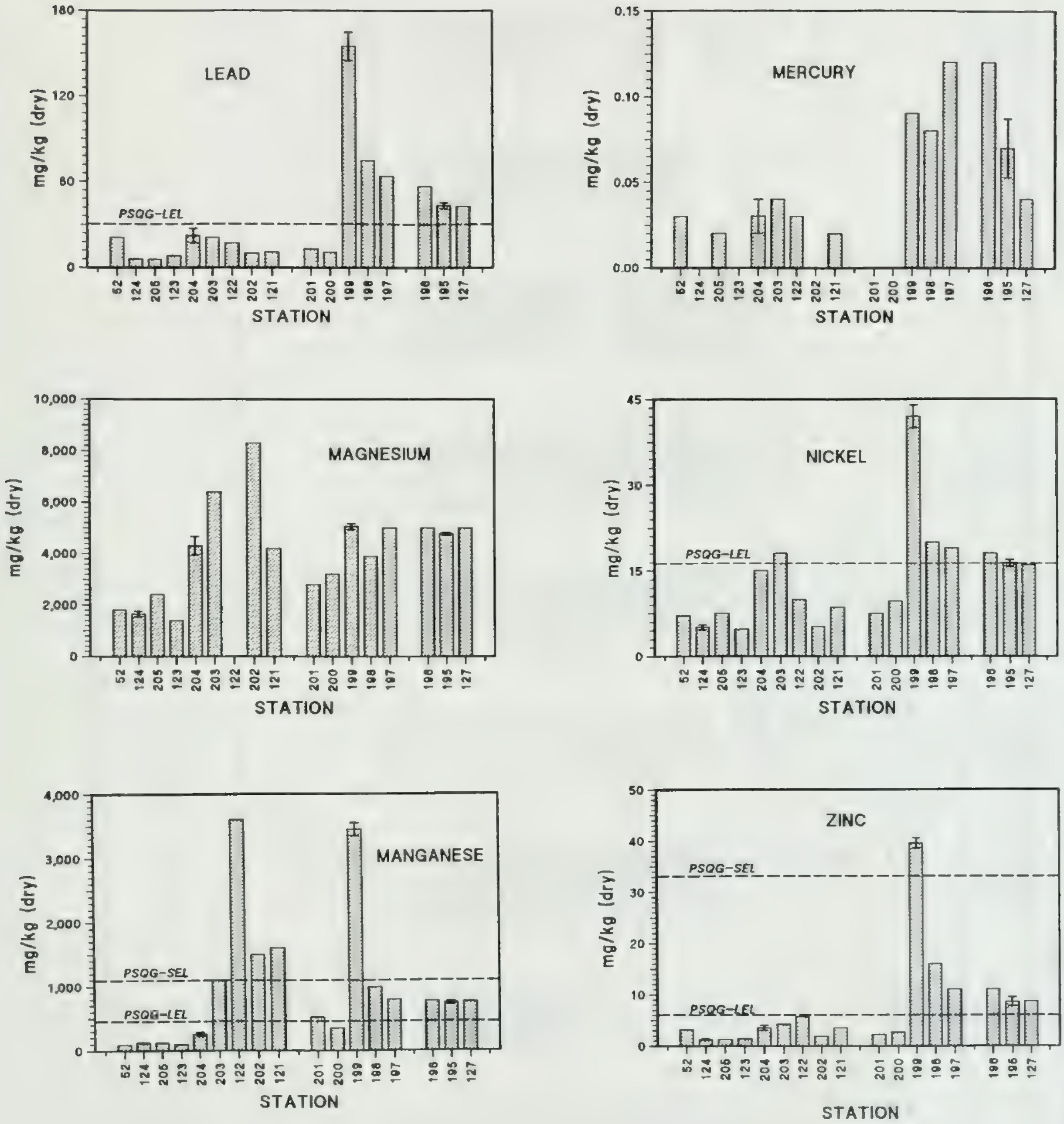

Figure 6. **Concentrations of lead, magnesium, manganese, mercury, nickel and zinc in sediments.** Vertical lines on bars represent one standard deviation of replicates (n = 3) or range of split samples (n = 2).

Table 6. Polycyclic aromatic hydrocarbons concentrations in sediments.

All concentrations in mg.kg^{-1} (ppm), dry weight.

Station Number	Ace-naph-thene	Ace-naph-thylene	Anthra-cene	Benzo(a)-anthra-cene	Benzo(b)-fluoran-thene	Benzo(k)-fluoran-thene	Benzo-(g,h,i)-perylyne	Benzo(a)-pyrene	Chry-sene	Dibenzo-(a,h)an-thracene	Fluor-anthene
Pointe aux Pins Bay											
52	0.04 <T	0.05 <W	0.01 <T	0.02 <T	0.06 <T	0.02 <T	0.04 <T	0.04 <T	0.04 <T	0.04 <T	0.08 <T
Algoma Slag Dump											
124-S	0.04 <T 0%	0.05 <W –	0.01 <T 0%	0.02 <T 0%	0.06 <T 0%	0.02 <T 0%	0.04 <T 0%	0.04 <T 0%	0.02 <T 0%	0.04 <T 0%	0.03 <T 0%
205	0.04 <T	0.05 <W	0.01 <T	0.02 <T	0.06 <T	0.02 <T	0.04 <T	0.04 <T	0.02 <T	0.04 <T	0.02 <T
123	0.04 <T	0.05 <W	0.01 <T	0.02 <T	0.06 <T	0.02 <T	0.04 <T	0.04 <T	0.02 <T	0.04 <T	0.02 <T
204-R	0.04 <T 0%	0.05 <W –	0.03 <T 33%	0.10 <T 20%	0.16 <T 6%	0.07 <T 14%	0.06 <T 35%	0.11 <T 18%	0.14 <T 14%	0.04 <T 0%	0.25 16%
203	0.04 <T	0.05 <W	0.05 <T	0.29	0.44 <T	0.21	0.22 <T	0.37 <T	0.37	0.06 <T	0.66
122	0.22 <T	0.29 <T	1.22	2.56	2.90	1.36	1.21	2.60	2.64	0.32 <T	5.47
202	0.04 <T	0.05 <W	0.09 <T	0.32	0.42 <T	0.18 <T	0.19 <T	0.37 <T	0.36	0.05 <T	0.61
121	0.04 <T	0.05 <W	0.15	0.68	1.00	0.47	0.49	0.92	0.79	0.13 <T	1.22
201	0.04 <T	0.05 <W	0.08 <T	0.36	0.50 <T	0.23	0.25 <T	0.44	0.41	0.06 <T	0.65
200	0.04 <T	0.05 <W	0.08 <T	0.25	0.37 <T	0.17 <T	0.18 <T	0.32 <T	0.30	0.05 <T	0.47
199-S	0.04 <T 0%	0.05 <W –	0.23 15%	0.73 29%	1.07 9%	0.38 5%	0.41 17%	0.78 11%	0.79 3%	0.12 <T 28%	1.41 8%
198	0.81	0.24 <T	1.20	3.55	4.97	1.64	2.46	4.28	3.40	0.71	5.86
197	0.52	0.25 <T	1.39	5.25	7.51	2.59	2.81	5.81	5.37	0.93	8.77
196	0.54	0.21 <T	1.48	5.01	6.81	2.48	2.47	5.31	4.97	0.78	8.75
195-R	0.78 18%	0.35 14%	2.10 18%	6.30 6%	8.07 4%	3.13 5%	3.40 5%	6.55 5%	6.36 4%	1.06 10%	11.77 13%
127	1.05	0.38 <T	2.23	6.29	7.52	2.89	3.17	6.17	6.29	1.05	13.09 >A
Dump Mean	0.27	0.11 <T	0.65	1.98	2.62	0.99	1.09	2.13	2.02	0.34	3.69
PSQG-LEL:	--	--	0.22	0.32	--	0.24	0.17	0.37	0.34	0.06	0.75
PSQG-SEL	--	--	370	1480	--	1340	320	1440	460	130	1020
OWDMDG	--	--	--		--	--	--	--	--	--	--

NOTES "--" indicates that guideline or CV is not available for this parameter

"<T" = a measurable trace amount interpret with caution

"<W" = no measurable response (zero) less than reported value

">A" = approximate result exceeded normal range limit

Underlined value in shaded cell exceeds PSQ-LEL Guideline

Percentages after concentrations are the Coefficient of Variation For n = 3, CV = (Std Dev'n /Mean) x 100, or for n = 2, CV = [square root of 2(max -min /min + max) x 100]

"S" after station number = split (same grab) sample, n = 2

"R" after station number = replicate (discrete grab) sample, n = 3

Table 6. continued.

All concentrations in mg.kg^{-1} (ppm), dry weight.

Station Number	Fluor-ene	Indeno-(1,2,3-cd)pyrene	Naph-thalene	Phen-anthrene	Pyrene	Total of 16 PAHs
Pointe aux Pins Bay						
52	0.04 <T	0.04 <T	0.04 <T	0.07 <T	0.06 <T	0.69
Algoma Slag Dump						
124-S	0.04 <T 0 %	0.04 <T 0 %	0.04 <T 0 %	0.07 <T 0 %	0.06 <T 0 %	0.57 0 %
205	0.04 <T	0.04 <T	0.04 <T	0.07 <T	0.06 <T	0.56
123	0.04 <T	0.04 <T	0.04 <T	0.07 <T	0.06 <T	0.56
204-R	0.04 <T 0 %	0.07 <T 14 %	0.13 <T 45 %	0.13 <T 22 %	0.19 <T 15 %	1.58 11 %
203	0.04 <T	0.27 <T	0.04 <T	0.23 <T	0.56 <T	3.85
122	0.50	1.40	0.50	3.39	4.24	30.82
202	0.04 <T	0.24 <T	0.04 <T	0.26 <T	0.49 <T	3.70
121	0.05 <T	0.60	0.06 <T	0.51 <T	1.00	8.11
201	0.04 <T	0.29 <T	0.05 <T	0.23 <T	0.54 <T	4.17
200	0.04 <T	0.23 <T	0.04 <T	0.19 <T	0.39 <T	3.12
199-S	0.10 <T 7 %	0.55 19 %	0.17 <T 8 %	0.72 13 %	1.31 7 %	8.86 1 %
198	1.10	3.30	3.56	3.64	5.16	45.88
197	0.80	3.90	1.64	4.92	7.61	60.07
196	0.85	3.40	1.72	5.16	7.33	57.27
195-R	1.24 18 %	4.53 6 %	2.39 15 %	7.73 13 %	8.99 11 %	74.76 7 %
127	1.60	4.30	3.40	8.81 >A	9.54 >A	77.78
Dump Mean:	0.41	1.45	0.87	2.26	2.97	23.85
PSQG-LEL:	0.19	0.20	--	0.56	0.49	4
PSQG-SEL:	160	320	--	950	850	10000
OWDMDG:	--	--	--	--	--	--

groundwater or runoff input(s) from the dump. The 1988-89 sampling of shallow perimeter monitoring wells on the dump (reflecting potential discharge to the St. Marys River) found the highest concentrations of cyanide near Station 203, with somewhat lower levels in wells near Stations 121, 197, 196, 195 and 127. Concentrations of cadmium in well samples were highest near Station 121, whereas iron and zinc were highest near Station 124 (Berry-Spark & Tossell, 1990).

Sediment Total PAH concentrations exceeded the PSQG-LEL of 4 $mg.kg^{-1}$ at nine of the 16 dump stations, with concentrations ranging from 4.17 $mg.kg^{-1}$ to 81.2 $mg.kg^{-1}$ in samples (Table 6). Also, concentrations of all 12 of the individual PAH compounds for which guidelines are currently available were above their respective PSQG-LELs. These compounds included: anthracene, benzo(a)anthracene, benzo(k)fluoranthene, benzo(g,h,i)perylene, benzo(a)pyrene, chrysene, dibenzo(a,h)anthracene, fluoranthene, fluorene, indeno(1,2,3-cd)pyrene, phenanthrene and pyrene. (None of the individual PAH compound or total PAH concentrations exceeded their respective PSQG-SELs at any of the stations sampled during this study.) As with many of the metals, concentrations of PAHs were highest near the eastern end of the slag dump (i.e., Stations 198, 197, 196, 195 and 127, with concentrations peaking at 127 - see Fig. 6). During 1988-89, monitoring of shallow monitoring wells installed around the perimeter of the dump detected parts Total PAHs at parts per billion ($\mu g.l^{-1}$) concentrations (Berry-Spark & Tossell, 1990). The highest concentrations were found at wells in the vicinity of Station 203, with somewhat lower levels in wells near Stations 205, 196, 195 and 127 (see Fig. 3).

Of the 16 unsubstituted PAHs analyzed for in the present study, fluoranthene, pyrene, benzo(b)-fluoranthene and phenanthrene were, on average, present at the highest concentrations (see Fig. 10). This pattern in sediments is consistent with that observed during a 1985 study (Kauss & Hamdy, 1991). It was suggested that high-temperature combustion, which occurs during the burning of coal and production of coke, was the major source of these compounds.

4.2.3 Relationships Between Contaminants

Correlation analysis (Appendix Table C-5) indicated that the proportion of silt and clay (i.e., "fines") in sediments only correlated significantly with copper concentrations, and iron concentrations were not significantly correlated with those of other analytes. Magnesium, chromium and Total PAHs concentrations correlated significantly ($p < 0.05$) with each other. Levels of all 16 of the PAH compounds were significantly correlated ($p < 0.05$) with each other ($r = 0.91$ to 1.0) in the sediments, as well as with arsenic, copper, cyanide, lead, mercury, nickel and zinc levels ($r = 0.49$ to 0.75), and with TOC content ($r = 0.72$ to 0.77). Consequently, concentrations of these analytes were TOC-normalized, assuming that the contaminants were only associated with the organic carbon particles in the sediments. The resultant concentration patterns (Fig. 11) are somewhat different from those of non-normalized data (Figs. 5 and 6). The highest arsenic, copper, cyanide, lead, mercury, nickel and zinc concentrations in sediment organic carbon would seem to be at the southeastern end of Leigh Bay (Stations 205 and/or 123) and at the middle of the south shore (Station 199). In contrast, the pattern for PAHs changed

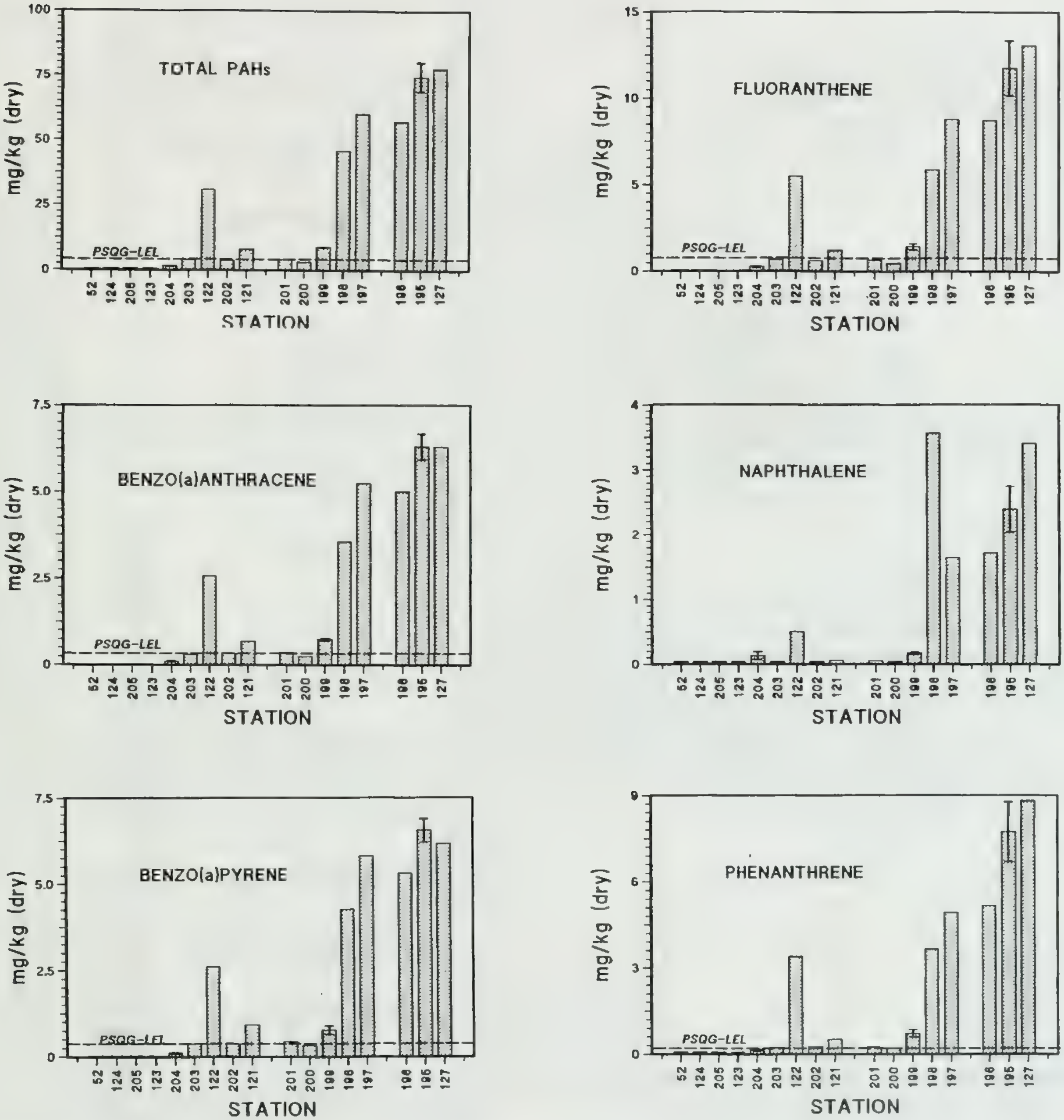

Figure 7. Concentrations of total polycyclic aromatic hydrocarbons (PAHs), benzo(a)anthracene, benzo(a)pyrene, fluoranthene, naphthalene and phenanthrene in sediments. Vertical lines on bars represent one standard deviation of replicates (n = 3) or range of split samples (n = 2).

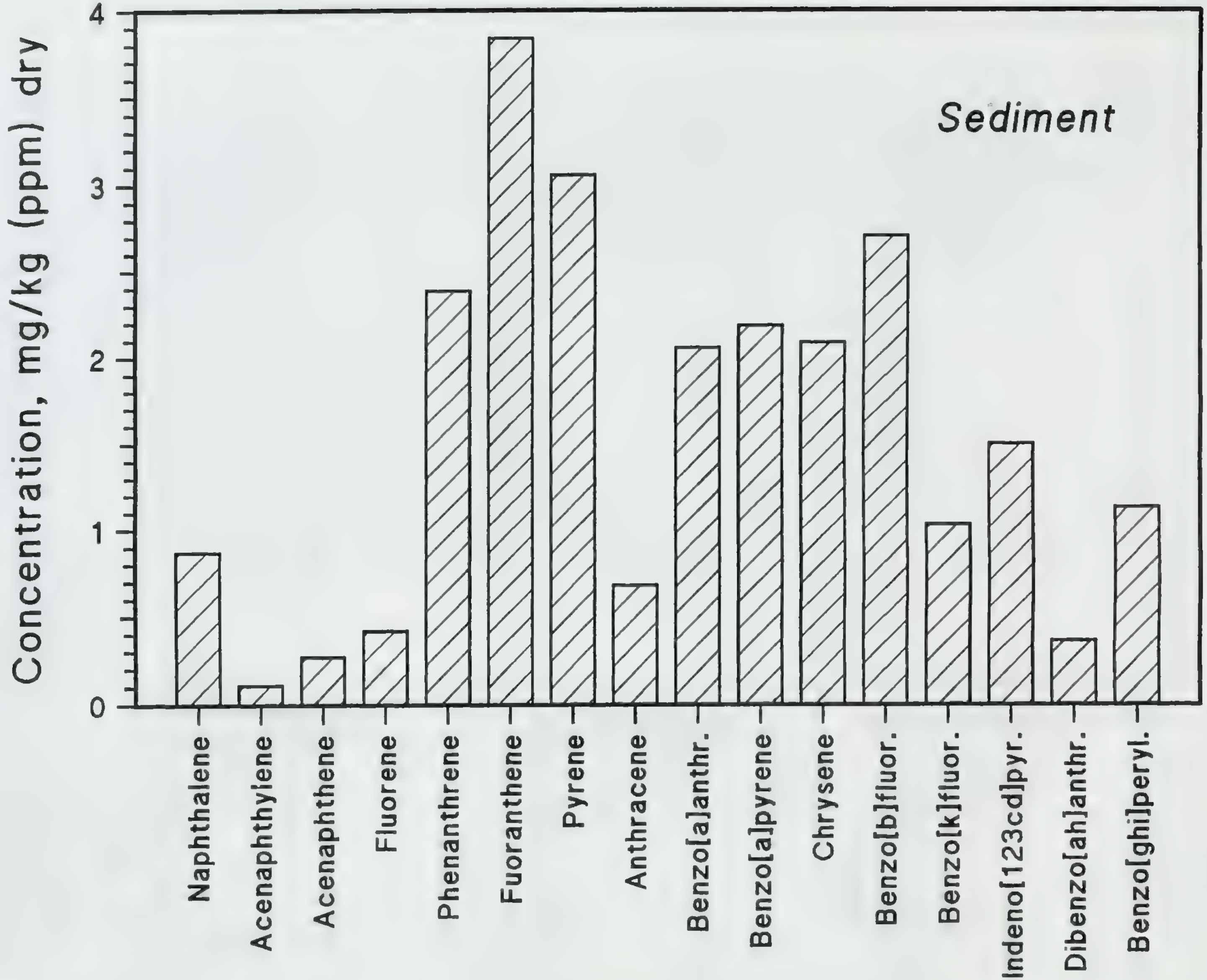

Figure 8. **Average PAH compound profile in sediments.** Compounds are listed order of decreasing water solubility, from left to right (Mackay *et al.*, 1992).

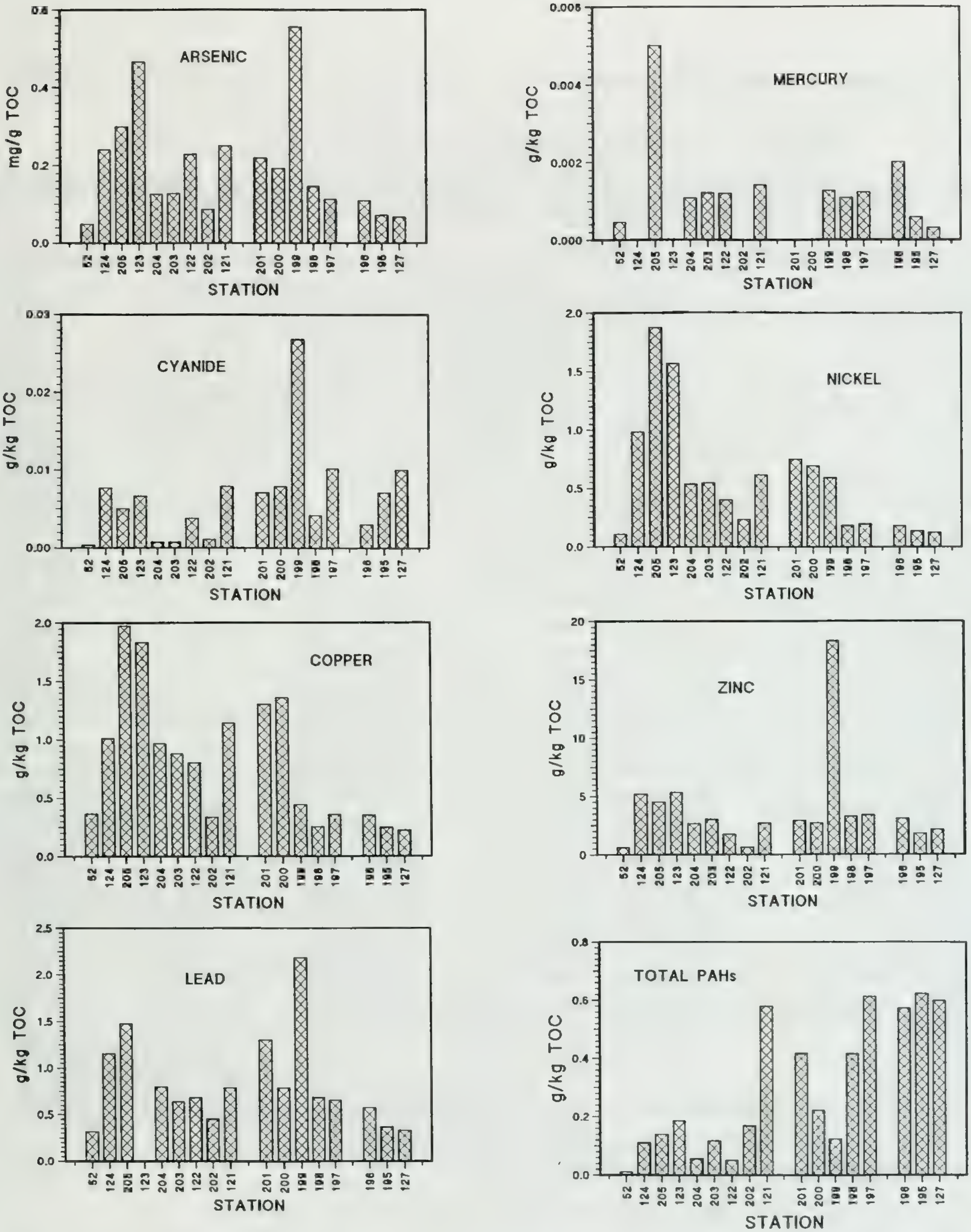

Figure 9. TOC-normalized concentrations of arsenic, cyanide, copper, lead, mercury, nickel, zinc and Total PAHs in sediments.

Table 7: **Comparison of 1987 and 1989 polycyclic aromatic hydrocarbons concentrations in surficial sediments from the Algoma Slag Dump and Point aux Pins Bay.** Concentrations in mg.kg^{-1} (ppm), dry weight.

Station:	52		124		121		127	
Compound Year:	1987	1989	1987	1989	1987	1989	1987	1989
TOC	28	66	22	5.50	17.5	14	**144**	**130**
Cadmium	0.50	0.87	0.44	0.13<T	0.58	0.23<T	1.04	0.32
Chromium	9.60	14	28	11	70	43	31	31
Copper	12	24	16	5.2	19	16	33	29
Iron	5400	7400	18000	7 350	21444	16000	**47400**	34000
Magnesium	970	1800	4100	1650	9 925	4200	5520	5000
Manganese	55	94	350	125	**3 156**	**1 600**	940	760
Nickel	4.20	7.10	12	5.10	9.40	8.60	15.4	16
Zinc	24	40	73	27	49	38	283	280
Solvent Extractables	1260	1106	651	326	3 474	380	3517	692
Acenaphthene	0.04<T	0.04<T	0.04	0.04<T	0.12	0.04<T	0.68	1.05
Acenaphthylene	0.04<T	0.05<W	0.04	0.05<W	0.11	0.05<W	0.36	0.38<T
Anthracene	0.01<T	0.01<T	0.01	0.01<T	0.31	0.15	2.01	2.23
Benzo(a)anthracene	0.02<T	0.02<T	0.04	0.02<T	1.21	0.68	4.26	6.29
Benzo((b)fluoranthene	0.06<T	0.06<T	0.06	0.06<T	1.60	1.00	3.48	7.52
Benzo(k)fluoranthene	0.02<T	0.02<T	0.02	0.02<T	1.56	0.47	2.24	2.89
Benzo(g,h,i)perylene	0.02<T	0.04<T	0.04<T	0.04<T	1.45	0.49	1.44	3.17
Benzo(a)pyrene	0.04<T	0.04<T	0.04	0.04<T	1.64	0.92	2.77	6.17
Chrysene	0.02<T	0.04<T	0.03	0.02<T	1.58	0.79	4.47	6.29
Dibenzo(a,h)anthracene	0.04<T	0.04<T	0.04	0.04<T	0.26	0.13<T	0.33	1.05
Fluoranthene	0.04	0.08<T	0.09	0.03<T	2.25	1.22	8.74	13.09>A
Fluorene	0.04<T	0.04<T	0.04	0.04<T	0.11	0.05<T	1.11	1.60
Indeno(1,2,3-cd)pyrene	0.04<T	0.04<T	0.04<T	0.04<T	1.56	0.60	1.42	4.30
Naphthalene	0.04<T	0.04<T	0.04<T	0.04<T	0.23	0.06<T	2.27	3.40
Phenanthrene	0.07<T	0.07<T	0.07<T	0.07<T	0.98	0.51<T	6.11	8.81>A
Pyrene	0.06<T	0.06<T	0.06<T	0.06<T	2.05	1.00	6.81	9.54>A
Total of 16 PAHs	0.60	0.64	0.67	0.57	14.97	8.11	48.5	77.78

NOTES: Values in shaded cells and underlined exceed PSQG-LEL or OWDMDG; those in bold type exceed PSQG-SEL (see Table 6).
"<T" = a measurable trace amount; interpret with caution.
"<W" = no measurable response (zero): less than reported value.

Table 8. Comparison of contaminants concentrations in sediments from other priority areas in the St. Marys River. Shaded cells contain the maximum value of the six areas. All concentrations are in mg.kg^{-1} (dry weight).

Parameter	Algoma Slag Dump [1]	Algoma Slip [2]	Belleview Marine Park [3]	Lake George Channel-East End WWTP [4]	Lake George Channel-Bells Point [5]	Little Lake George [6]	Lake George [7]
Arsenic	1.2 - 40	5.1 - 11	(14 - 17)	1.6 - 11	20	3.6 - 6.2	1.3 - 15
Cyanide	0.01<W - 2.20	0.01 - 1.60	(1.70 - 2.30)	0.014<T - 0.590	2.80	0.310 - 0.470	0.300 - 0.550
Cadmium	0.13<T - 1.40	0.05 - 0.95	0.73 - 2.60	0.24<T - 1.20	1.80 - 2.40	0.24<T - 0.69<T	0.20 - 1.10
Chromium	9.7 - 74	21 - 58	42 - 330	22 - 98	75 - 110	38 - 49	11 - 55
Copper	5.1 - 35	15 - 43	29 - 110	14 - 87	97 - 100	36 - 43	7.3 - 59
Iron	7200 - 170000	24000 - 60000	32000 - 115000	8900 - 61000	58000 - 81000	15000 - 21000	8600 - 42000
Lead	5.9 - 160	16 - 46	42 - 310	15 - 90	130 - 160	28 - 36	3.8 - 68
Magnesium	1400 - 16000	3067 - 14000	2500 - 7100	1600 - 3887	4700 - 5400	2800 - 3800	--
Manganese	96 - 3600	533 - 2000	380 - 7100	110 - 700	780 - 830	200 - 280	100 - 640
Mercury	0.01<W - 0.09	0.02 - 0.18	(0.14 - 0.16)	0.02<T - 0.34	0.24	0.01<W - 0.07	0.01<T - 0.21
Nickel	4.9 - 43	13 - 38	15 - 54	7.2 - 27	37 - 47	13 - 18	3.6 - 25
Zinc	14 - 1300	65 - 250	75 - 630	54 - 300	380 -450	86 - 140	21 - 260
Solvent Extractables	222 - 3264	588 - 10870	695 - 19200	194 - 3814	280 - 989	2233 - 2340	2850 - 3165
Acenaphthene	0.04<T - 1.05	0.10 - 32.0	0.05<T - 0.80	0.04<T - 0.11	0.08 - 0.10	0.02<W-0.04<T	0.02<W
Acenaphthylene	0.05<W - 0.40<T	0.07 - 6.55	0.10 - 0.88	0.05<T - 0.18	0.13 - 0.15	.0.05<T-0.024<T	0.07
Anthracene	0.01<T - 2.53	0.18 - 90.8	0.23 - 2.23	0.02<T - 0.39	0.24 - 0.36	0.039<T - 0.06	0.07
Benzo(a)anthracene	0.02<T - 6.64	0.76 - 90.0	0.92 - 3.04	0.15 - 1.34	0.74 - 1.50	0.02<W - 0.31	0.28
Benzo(b)fluoranthene	0.06<T - 8.30	1.00 - 56.6	0.91 - 3.66	0.17 - 2.20	0.89 - 2.30	0.028<T - 0.43	0.33
Benzo(k)fluoranthene	0.02<T - 3.26	0.38 - 30.0	0.91 - 3.66	0.10<T - 1.02	0.89 - 1.00	0.024<T - 0.32	--
Benzo(g,h,i)perylene	0.04<T - 3.52	0.43 - 21.9	0.25 - 2.55	0.07 - 0.95	0.65 - 0.89	0.04<W-0.26<T	0.07
Benzo(a)pyrene	0.04<T - 6.75	0.77 - 50.0	0.55 - 3.08	0.14 - 1.71	0.77 - 1.70	0.024<T - 0.38	0.21
Chrysene	0.02<T - 6.59	0.83 - 90.7	0.84 - 4.67	0.21 - 1.88	0.78 - 2.00	0.021<T - 0.40	0.06
Dibenzo(a,h)anthracene	0.04<T - 1.15	0.13 - 6.19	0.14 - 0.78	0.04<T - 0.35	0.14 - 0.30	0.04<W-0.09<T	0.03
Fluoranthene	0.03<T - 13.6	1.50 - 490	1.80 - 10.5	0.31 - 2.78	1.58 - 3.60	0.027<T - 0.61	0.43
Fluorene	0.04<T - 1.60	0.11 - 140	0.10 - 1.23	0.04<T - 0.13	0.11 - 0.11	0.02<W-0.04<T	0.03
Indeno(1,2,3-cd)pyrene	0.04<T - 4.70	0.62 - 26.3	0.33 - 2.01	0.08 - 1.15	0.66 - 0.96	0.04<W-0.37<T	0.07
Naphthalene	0.04<T - 3.56	0.31 - 340	0.04 - 6.98	0.04<T - 1.20	0.20 - 0.58	0.07 - 0.17<T	013
Phenanthrene	0.07<T - 8.81	0.88 - 720	0.80 - 8.85	0.10 - 1.30	0.89 - 1.30	0.02<W - 0.23	0.25
Pyrene	0.06<T - 10.1>A	1.20 - 340	1.89 - 7.84	0.27 - 2.38	1.34 - 3.10	0.023<T - 0.52	0.27
Total of 16 PAHs	0.56 - 81.2	18.5 - 2389	12.2 - 61.5	0.86 - 7.95	9.16 - 10.4	0.19 - 3.46	2.30

NOTES: "--" = no data available.
"nd" = not detected.
"<T" = a measurable trace amount: interpret with caution
"<W" = no measurable response (zero): less than reported value.

Data Sources:
1 - data from this study, excluding results for Station 52.
2 - data from 16 stations sampled in 1990 (Pope & Kauss, 1995).
3 - data from 7 stations sampled in 1987 (unpublished OMOE data) & 1 station in 1992 for data in brackets (Arthur & Kauss, 1999).
4 - data from 12 stations sampled downstream of East End WWTP discharge in 1989 (Kauss & Nettleton, 1995).
5 - range of data from 1 station sampled in 1987 (OMOE, unpubl. data) & in 1989 (Kauss & Nettleton, 1995).
6 - range of data from 1 station sampled in 1989 (Kauss & Nettleton, 1995) & in 1992 (Arthur & Kauss, 1999).
7 - data from 22 stations sampled in 1985 for metals (Burt et al., 1988) & 1 station sampled for PAHs (Kauss & Hamdy, 1991).

only slightly from the non-normalized concentrations.

4.2.4 Contaminants Temporal Trends

Arsenic, heavy metals and PAH concentrations in sediments sampled in 1989 as well as in 1987 at Stations 52, 124, 121 and 127 are summarized in Table 7. Changes in contaminant levels over the two years were variable, with regards to both station location and contaminant. For example, TOC and a number of the metals increased in concentration between 1987 and 1989 at Station 52, but decreased at the slagb dump stations. Sediment PAH levels in Point aux Pins Bay (Station 52) and Leigh Bay (Station 124) were close to or below the MRVs in 1987 and 1989, and concentrations (e.g., Total PAHs) have not changed at these two sites over the two years between surveys. In contrast, concentrations decreased about four-fold at Station 121 and increased two-fold at Station 127 over the same period. This may be due to the natural heterogeneity of sediments in this area. In this regard, the coefficients of variation for concentrations in 1989 replicate grab samples were usually similar to or higher than the CVs for split samples (see Tables 3, 5 and 6), suggesting that this variability was related to local spatial heterogeneity of the sediments, and not to sample handling and/or analytical variability. Periodic disturbance or movement of the sediments can occur from physical factors such as wind-induced currents (storms), wakes, prop wash or dragging of anchors by large vessels using the nearby Algoma Slip, ice scour. As shown by the sediment data summarized in Appendix A, there were marked within-year differences in some sediment quality parameters at stations sampled along the Slag Dump shore in 1987. Finally, the periodic addition of slag to the shoreline and construction of the A.B. MacLean docking facilty has undoubtedly changed the nature and distribution of sediments adjacent to some sections of the dump.

4.2.5 Comparison of Concentrations With Other Areas

Sediment contamination associated with discharges from the Sault Ste. Marie area has been monitored at other locations or areas in the St. Marys River. Table 8 compares inorganic and organic contaminant concentrations in sediments with six other downstream areas. With few exceptions, all of the maximum arsenic and heavy metal concentrations in sediments from this group of locations exceeded the respective PSQG-LELs, and in some areas, also exceeded the applicable PSQG-SELs (cf. Tables 5 and 8). The maximum concentrations of Total PAHs and of many individual PAH compounds in all areas also exceeded their respective PSQG-LELs, particularly in the Slag Dump, Algoma Slip, Belleview Marine Park and Lake George Channel areas (cf. Tables 6 and 8). Overall, the group maximum concentrations of cyanide, a number of heavy metals and solvent extractables were found in Belleview Marine Park sediments, whereas Algoma Slip sediments contained the highest maximum levels of all a6 of the PAHs analyzed for. In contrast, only the arsenic, iron, magnesium and zinc maxima were found within the 1989 Algoma Slag Dump sediment data.

Table 9. Arsenic and heavy metals concentrations in mussel tissues.
All concentrations in $mg.kg^{-1}$ (ppm), wet weight.

Station Number	Sample Date	Arsenic		Cadmium		Copper		Lead		Magnesium		Manganese		Mercury		Nickel	
Balsam Lake:																	
1	89/08/15	0.63 +/-0.41	A	1.400 +/-0.360	A	1.33 +/-0.15	A	0.60 +/-0.30	AB	233 +/-58	AB	1193 +/-526	A	0.01 +/-0.01	A	0.180 +/-0.030	A
Pointe aux Pins Bay:																	
52	NA	--		--		--		--		--		--		--		--	
Algoma Slag Dump:																	
124	NA	--		--		--		--		--		--		--		--	
205	89/09/08	0.33 +/-0.11	A	0.840 +/-0.550	A	1.97 +/-0.55	A	0.65 +/-0.26	AB	262 +/-22	AB	913 +/-338	A	0.01 +/-0.01	A	0.470 +/-0.060	A
123	"	0.61 +/-0.09	A	0.670 +/-0.330	A	2.27 +/-0.31	A	0.94 +/-0.32	B	183 +/-45	AB	467 +/-306	A	0.01 <W	A	0.220 +/-0.030	A
204	"	0.40 +/-0.08	A	0.580 +/-0.240	A	1.43 +/-0.32	A	0.61 +/-0.22	AB	187 +/-38	AB	480 +/-161	A	0.01 +/-0.01	A	0.470 +/-0.060	A
203	"	0.49 +-/0.19	A	0.820 +/-0.420	A	2.13 +/-0.61	A	0.41 +/-0.20	AB	231 +/-68	AB	622 +/-470	A	0.03 +/-0.01	A	0.200 +/-0.000	A
122	"	0.46 +/-0.07	A	0.580 +/-0.380	A	2.77 +/-1.00	A	0.35 +/-0.00	A	208 +/-60	AB	760 +/-498	A	0.01 +/-0.01	A	0.250 +/-0.000	A
202	NA	--		--		--		--		--		--		--		--	
121	89/09/08	0.48 +/-0.14	A	0.670 +/-0.480	A	1.70 +/-0.56	A	0.32 +/-0.03	A	181 +/-71	A	667 +/-722	A	0.01 <W	A	0.220 +/-0.030	A
121-M	"	0.38 +/-0.16	A	0.860 +/-0.11	A	1.73 +/-0.42	A	0.30 +/-0.05	A	264 +/-40	AB	1030 +/-675	A	0.01 +/-0.01	A	0.200 +/-0.000	A
201	"	0.46 +/-0.18	A	0.930 +/-0.190	A	1.93 +/-0.06	A	0.30 +/-0.00	A	239 +/-82	AB	1043 +/-703	A	0.01 <W	A	0.200 +/-0.000	A
200	"	0.36 +/-0.18	A	0.560 +/-0.270	A	1.30 +/-0.26	A	0.33 +/-0.03	A	231 +/-15	AB	1300 +/-173	A	0.01 +/-0.01	A	0.230 +/-0.030	A
199	NA	--		--		--		--		--		--		--		--	
198	89/09/08	0.40 +/-0.12	A	0.710 +/-0.340	A	1.63 +/-0.84	A	0.47 +/-0.15	AB	226 +/-13	AB	617 +/-311	A	0.01 +/-0.01	A	0.200 +/-0.000	A
197	"	0.46 +/-0.19	A	0.770 +/-0.250	A	1.93 +/-0.47	A	0.44 +/-0.20	AB	226 +/-72	AB	851 +/-693	A	0.01 <W	A	0.220 +/-0.030	A
197-M	"	0.31 +/-0.01	A	0.780 +/-0.480	A	2.40 +/-0.35	A	0.38 +/-0.10	A	284 +/-45	AB	1140 +/-295	A	0.01 <W	A	0.220 +/-0.030	A
196	"	0.40 +/-0.15	A	0.670 +/-0.170	A	1.87 +/-0.35	A	0.46 +/-0.28	AB	247 +/-10	AB	1123 +/-166	A	0.07 +/-0.12	A	0.220 +/-0.030	A
195	"	0.54 +/-0.25	A	0.970 +/-0.350	A	1.60 +/-0.10	A	0.59 +/-0.21	AB	252 +/-49	AB	900 +/-340	A	0.01 <W	A	0.200 +/-0.050	A
127	"	0.37 +/-0.10	A	0.810 +/-0.190	A	1.83 +/-0.06	A	0.35 +/-0.05	A	295 +/-82	AB	1589 +/-543	A	0.01 +/-0.02	A	0.230 +/-0.030	A
127-M	"	0.41 +/-0.07	A	1.300 +/-0.260	A	2.20 +/-0.56	A	0.30 +/-0.00	A	352 +/-87	B	1733 +/-153	A	0.02 +/-0.02	A	0.370 +/-0.160	A
Dump Mean & S. D.:		0.44 +/-0.08		0.737 +/-0.132		1.87 +/-0.38		0.48 +/-0.18		228 +/-33		872 +/-328		0.01 +/-0.01		0.256 +/-0.096	

NOTES: station values are arithmetic mean and standard deviation ($n = 3$)

"--" indicates that data is not available for this parameter or sample

"M" = mid-depth exposure; all others on bottom

"NA" = not available; cages lost

"<W" = no measurable response (zero): less than reported value

means followed by different letters are significantly different (MANOVA and Tukeys HSD test, $p < 0.05$)

Table 9. continued.

All concentrations in mg.kg^{-1} (ppm), wet weight.

Station Number	Sample Date	Zinc			Moisture %		
Balsam Lake							
1	89/08/15	36.7	+/-9.00	A	82.7	+/-0.6	ABC
Pointe aux Pins Bay							
52	NA	--			--		
Algoma Slag Dump							
124	NA	--			--		
205	89/09/08	33.7	+/-7.00	A	84.0	+/-1.0	ABCD
123	"	24.0	+/-4.40	A	86.7	+/-1.5	D
204	"	32.0	+/-10.8	A	85.7	+/-1.1	CD
203	"	31.3	+/-11.5	A	85.0	+/-1.0	BCD
122	"	29.0	+/-8.20	A	83.3	+/-2.1	ABCD
202	NA	--			--		
121	89/09/08	26.0	+/-13.0	A	82.3	+/-0.58	ABC
121-M	"	33.3	+/-2.50	A	84.0	+/-2.0	ABCD
201	"	37.7	+/-13.6	A	81.7	+/-0.6	AB
200	"	40.0	+/-1.70	A	83.3	+/-0.6	ABCD
199	NA	--			--		
198	89/09/08	31.0	+/-2.60	A	82.7	+/-1.5	ABC
197	"	38.3	+/-14.2	A	81.3	+/-0.6	A
197-M	"	41.3	+/-9.30	A	82.0	+/-1.0	AB
196	"	37.7	+/-7.40	A	83.0	+/-0.0	ABC
195	"	37.7	+/-9.10	A	82.7	+/-1.5	ABC
127	"	45.7	+/-18.0	A	84.7	+/-0.6	ABCD
127-M	"	51.3	+/-10.2	A	83.7	+/-1.1	ABCD
Dump Mean & S. D.:		34.2	+/-6.1		83.6	+/-1.6	

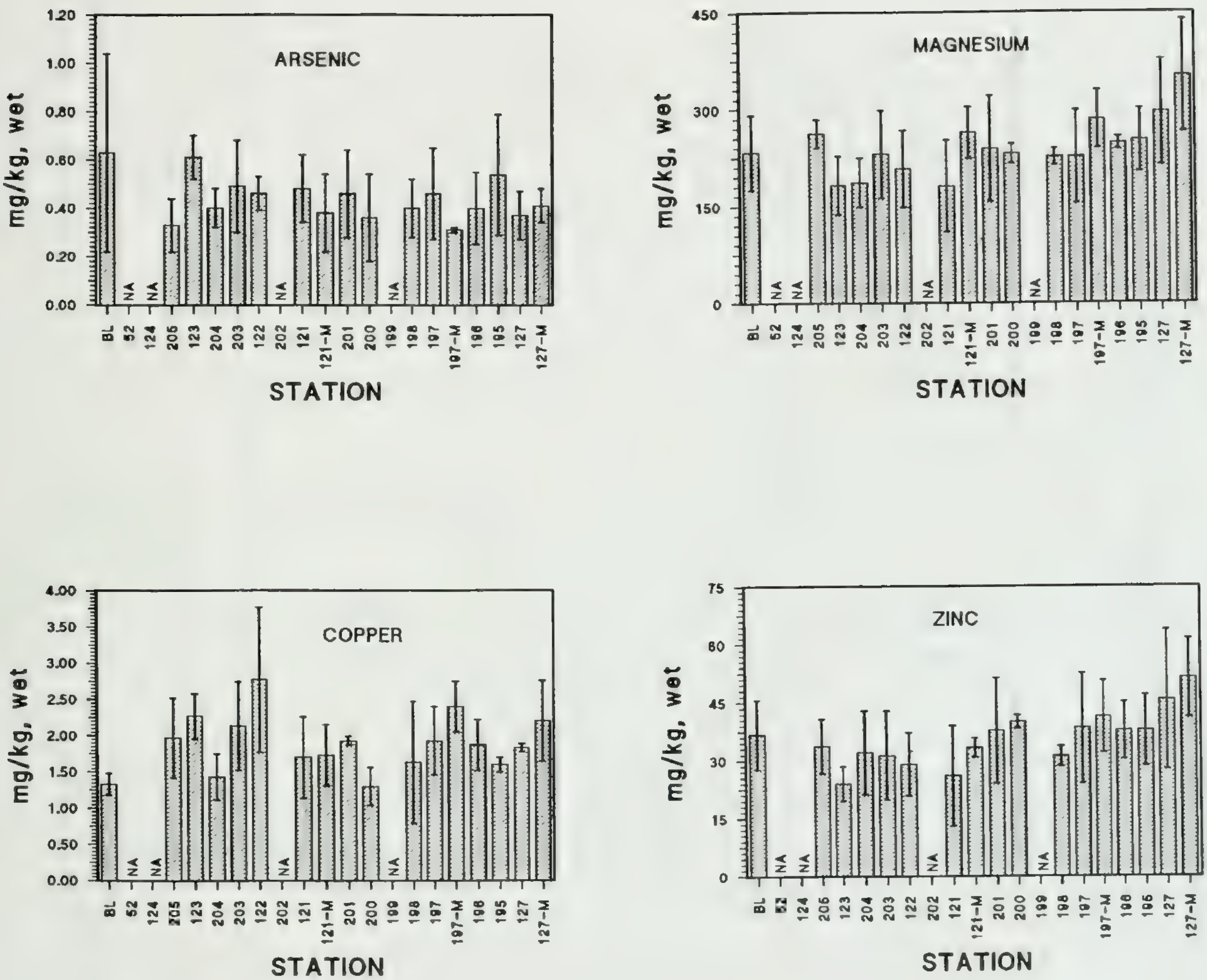

Figure 10. **Concentrations of arsenic, copper, magnesium and zinc in mussels.** Vertical lines on bars represent one standard deviation (n = 3).

Table 10. Polycyclic aromatic hydrocarbons concentrations in mussel tissues.
All concentrations in ug.kg^{-1} (ppb), wet weight.

Station Number	Sample Date	Ace-naph-thene	Ace-naph-thylene	Anthra-cene	Benzo(a)-anthra-cene	Benzo(b)-fluoran-thene	Benzo(k)-fluoran-thene	Benzo-(g,h,i)-perylyne	Benzo(a)-pyrene	Chry-sene	Dibenzo-(a,h)an-thracene
Balsam Lake											
1	89/08/15	12 +/-3 ABCD	5 <W A	11 +/-0 ABC	3 +/-4 A	7 <W A	8 +/-7 A	6 <W A	8 <W A	9 +/-2 A	7 <W A
Pointe aux Pins Bay											
52	NA	--	--	--	--	--	--	--	--	--	--
Algoma Slag Dump											
124	NA	--	--	--	--	--	--	--	--	--	--
205	89/09/08	7 +/-6 AB	5 <W A	7 +/-7 AB	2 +/-3 A	7 <W A	6 <W A	6 <W A	8 <W A	8 +/-1 A	7 <W A
123	"	12 +/-6 ABCD	5 <W A	14 +/-3 ABC	3 +/-4 A	7 <W A	7 +/-12 A	6 <W A	8 <W A	11 +/-2 A	7 <W A
204	"	14 +/-5 ABCD	5 <W A	12 +/-3 ABC	2 +/-3 A	7 <W A	6 <W A	6 <W A	8 <W A	8 +/-2 A	7 <W A
203	"	11 +/-10 ABCD	5 <W A	13 +/-6 ABC	3 +/-6 A	7 <W A	4 +/-6 A	6 <W A	3 ?? A	9 +/-3 A	7 <W A
122	"	10 +/-8 ABC	5 <W A	7 +/-6 AB	2 +/-3 A	7 <W A	6 <W A	6 <W A	8 <W A	5 +/-5 A	7 <W A
202	NA	--	--	--	--	--	--	--	--	--	--
121	89/09/08	8 <W A	5 <W A	9 <W A	4 +/-4 A	7 <W A	6 <W A	6 <W A	3 ?? A	11 +/-3 A	7 <W A
121-M	"	8 <W A	5 <W A	9 <W A	5 +/-1 A	7 <W A	6 <W A	6 <W A	8 <W A	9 +/-2 A	7 <W A
201	"	8 <W A	5 <W A	9 <W A	5 <W A	7 <W A	6 <W A	6 <W A	8 <W A	5 +/-5 A	7 <W A
200	"	8 <W A	5 <W A	9 <W A	5 <W A	7 <W A	6 <W A	6 <W A	8 <W A	7 +/-1 A	7 <W A
199	NA	--	--	--	--	--	--	--	--	--	--
198	89/09/08	39 +/-10 ABCD	4 +/-3 AB	15 +/-2 ABC	22 +/-8 AB	27 +/-7 AB	12 +/-12 A	6 <W A	8 <W A	47 +/-18 AB	2 ?? A
197	"	49 +/-9 BCD	7 +/-1 BC	23 +/-4 BCD	57 +/-14 B	97 +/-13 DE	23 +/-40 A	6 <W A	17 +/-16 A	97 +/-12 CDE	7 <W A
197-M	"	53 +/-7 CD	3 +/-5 AB	25 +/-3 CD	52 +/-20 B	80 +/-7 CD	6 <W A	6 <W A	7 +/-13 A	115 +/-28 DE	7 <W A
196	"	174 +/-24 F	18 +/-2 E	65 +/-9 E	103 +/-37 C	130 +/-45 E	6 <W A	6 <W A	49 +/-22 B	136 +/-38 E	7 <W A
195	"	157 +/-14 F	15 +/-1 DE	57 +/-6 E	51 +/-16 B	62 +/-23 BCD	18 +/-31 A	6 <W A	10 +/-17 A	72 +/-20 BCD	7 <W A
127	"	104 +/-46 E	11 +/-4 CD	36 +/-18 D	49 +/-9 B	53 +/-15 BC	27 +/-23 A	6 <W A	10 +/-17 A	64 +/-6 BC	7 <W A
127-M	"	54 +/-12 D	4 +/-4 AB	15 +/-2 ABC	34 +/-4 AB	42 +/-14 BC	6 +/-10 A	6 <W A	8 <W A	54 +/-5 B	7 <W A
Dump Mean & S D		43 +/-56	4 +/-6	18 +/-20	24 +/-31	31 +/-43	6 +/-15	6 <W	6 +/-15	41 +/-45	7 <W

NOTES values are arithmetic mean and standard deviation (n = 3)
"--" indicates that data is not available for this parameter or sample
"M" after station number indicates mid-depth exposure, all others on bottom
"NA" = not available; cages lost
"<W" = no measurable response (zero) less than reported value
means followed by different letters are significantly different (MANOVA and Tukeys HSD test, p < 0 05)

Table 10. continued.

All concentrations in $ug.kg^{-1}$ (ppb), wet weight.

Station Number	Sample Date	Fluor-anthene		Fluor-ene		Indeno-(1,2,3-cd)pyrene		Naph-thalene		Phen-anthrene		Pyrene		Total of 16 PAHs		Lipids %	
Balsam Lake																	
1	89/08/15	20 +/-1	A	26 +/-4	AB	6 <W	A	54 +/-6	AB	118 +/-3	ABC	15 +/-1	A	275 +/-5	A	0.33 +/-0.10	AB
Pointe aux Pins Bay:																	
52	NA	--		--		--		--		--		--		--	--		
Algoma Slag Dump:																	
124	NA	--		--		--		--		--		--		--	--		
205	89/09/08	21 +/-2	A	21 +/-5	AB	6 <W	A	15 +/-13	A	98 +/-25	ABC	16 +/-7	A	198 +/-55	A	0.31 +/-0.10	A
123	"	26 +/-3	A	30 +/-8	AB	6 +/-11	A	26 +/-4	A	137 +/-34	ABC	16 +/-2	A	288 +/-51	A	0.40 +/-0.05	AB
204	"	24 +/-5	A	31 +/-7	AB	9 +/-16	A	28 +/-5	A	133 +/-32	ABC	15 +/-3	A	276 +/-63	A	0.41 +/-0.14	AB
203	"	27 +/-6	A	26 +/-10	AB	19 +/-23	A	25 +/-8	A	123 +/-56	ABC	19 +/-5	A	277 +/-86	A	0.33 +/-0.08	AB
122	"	20 +/-10	A	18 +/-16	AB	6 <W	A	28 +/-6	A	86 +/-51	AB	15 +/-10	A	188 +/-115	A	0.38 +/-0.09	AB
202	NA	--		--		--		--		--		--		--		--	
121	89/09/08	19 +/-6	A	7 +/-13	A	49 +/-25	A	29 +/-11	A	39 +/-18	A	14 +/-5	A	127 +/-20	A	0.50 +/-0.07	AB
121-M	"	16 +/-2	A	16 <W	A	36 +/-37	A	19 +/-1	A	29 +/-2	A	11 +/-1	A	106 +/-34	A	0.36 +/-0.05	AB
201	"	18 +/-6	A	16 <W	A	6 <W	A	29 +/-1	A	41 +/-3	A	12 +/-4	A	105 +/-16	A	0.53 +/-0.13	AB
200	"	4 +/-8	A	16 <W	A	6 <W	A	7 +/-12	A	20 +/-3	A	3 +/-5	A	41 +/-15	A	0.30 +/-0.02	A
199	NA	--		--		--		--		--		--		--		--	
198	89/09/08	136 +/-47	B	49 +/-10	AB	6 <W	A	186 +/-22	BC	183 +/-21	ABC	101 +/-39	B	821 +/-177	B	0.62 +/-0.22	B
197	"	228 +/-10	CD	70 +/-12	B	17 +/-25	A	241 +/-52	C	261 +/-53	BCD	187 +/-4	CD	1349 +/-95	CD	0.57 +/-0.09	AB
197-M	"	309 +/-77	DE	74 +/-10	B	6 <W	A	229 +/-34	C	286 +/-41	CD	231 +/-51	DE	1464 +/-85	D	0.60 +/-0.12	AB
196	"	320 +/-29	E	228 +/-30	D	6 <W	A	681 +/-101	E	728 +/-90	E	254 +/-26	E	2698 +/-146	E	0.62 +/-0.09	B
195	"	265 +/-47	DE	203 +/-18	D	6 <W	A	600 +/-36	E	673 +/-61	E	200 +/-35	DE	2361 +/-149	E	0.49 +/-0.07	AB
127	"	170 +/-30	BC	141 +/-62	C	6 <W	A	417 +/-145	D	420 +/-208	D	138 +/-22	BC	1618 +/-509	D	0.34 +/-0.14	AB
127-M	"	118 +/-11	B	68 +/-12	B	6 <W	A	260 +/-54	C	186 +/-24	ABC	94 +/-9	B	936 +/-136	BC	0.42 +/-0.08	AB
Dump Mean & S. D.:		108 +/-115		60 +/-71		8 +/-21		176 +/-218		215 +/-220		83 +/-90		806 +/-9846		0.45 +/-0.14	

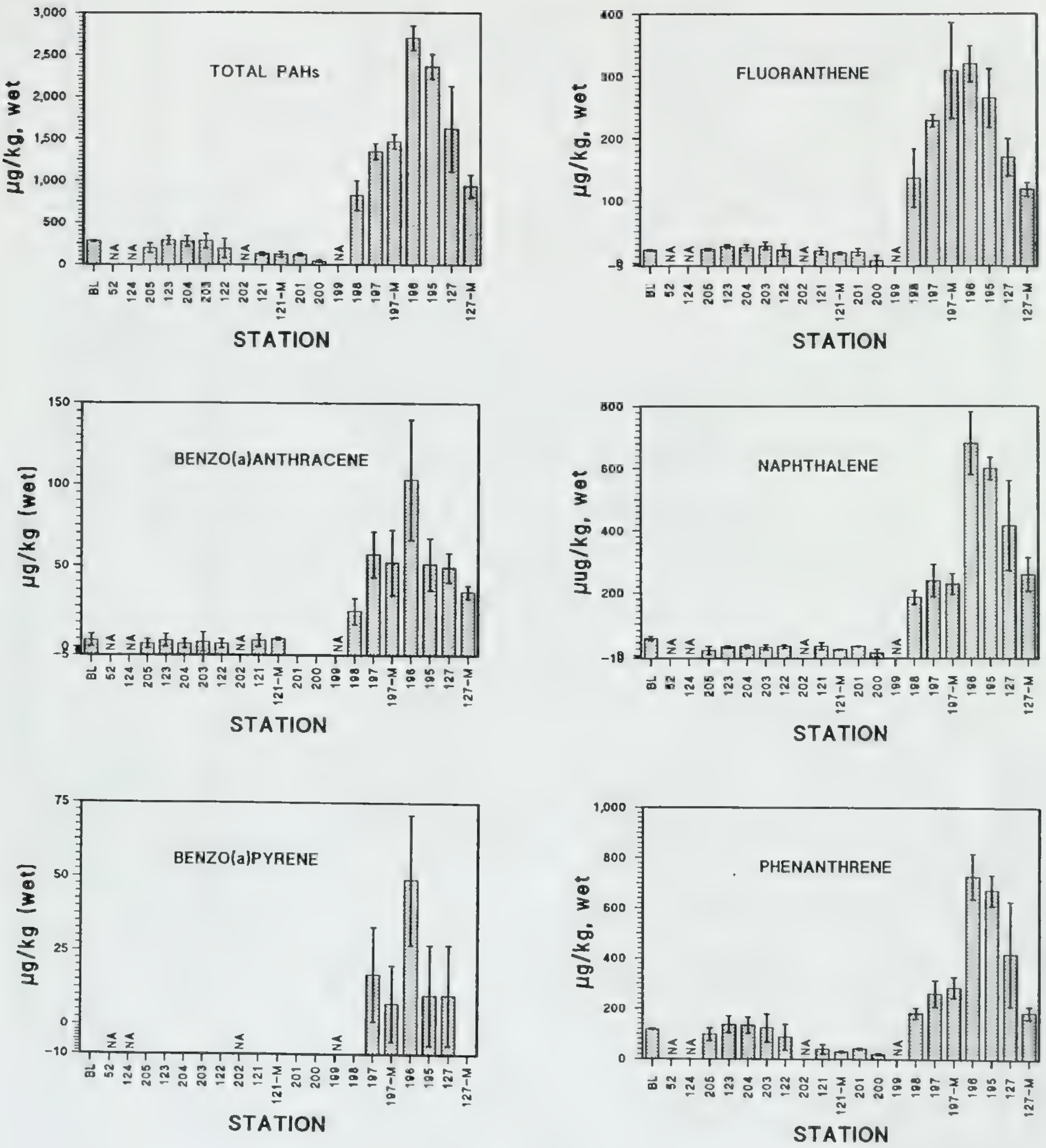

Figure 11. **Concentrations of total polycyclic aromatic hydrocarbons (PAHs), benzo(a)anthracene, benzo(a)pyrene, fluoranthene, naphthalene and phenanthrene in mussels.** Vertical lines on bars represent one standard deviation (n = 3).

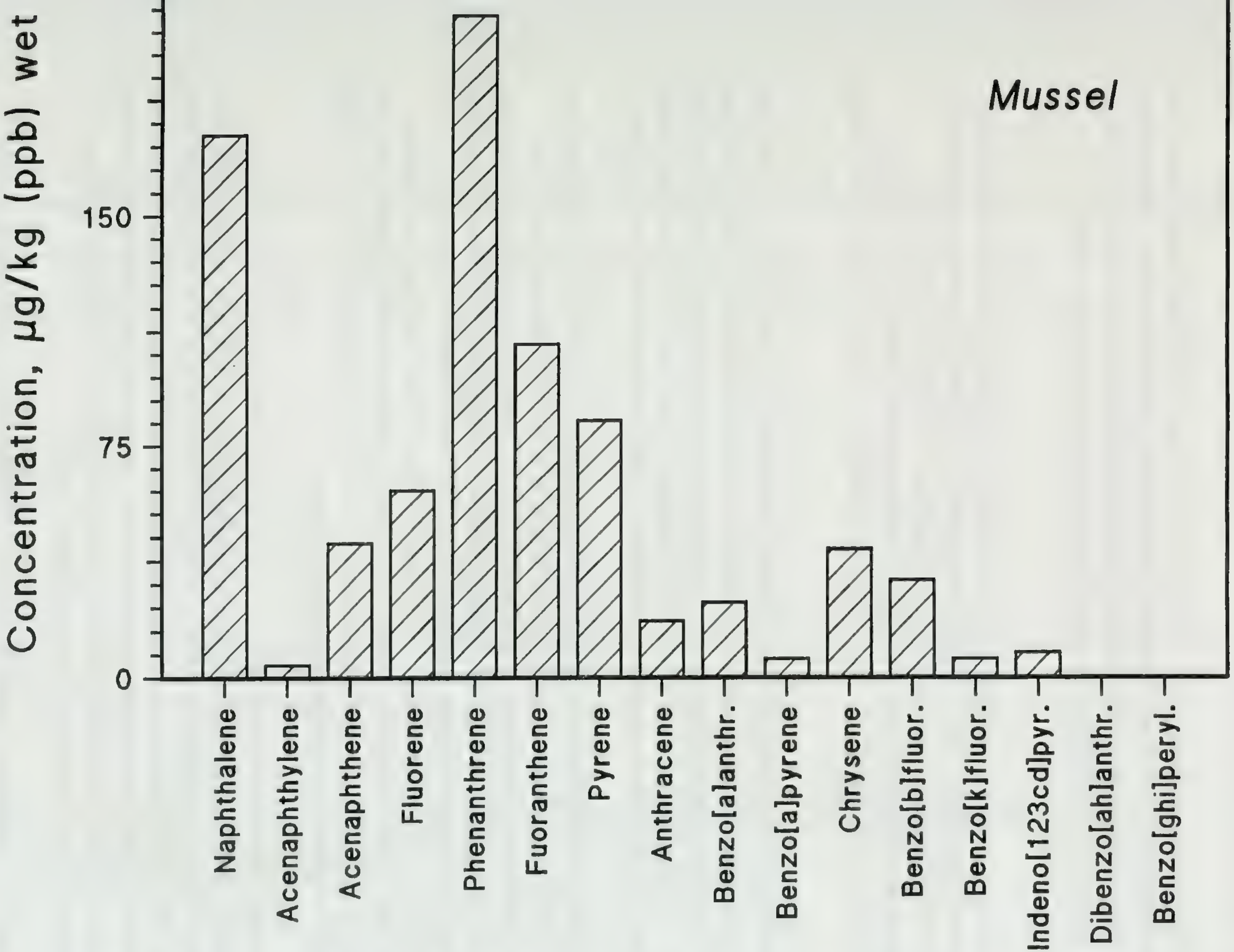

Figure 12. **Average PAH compound profile in mussels.** Compounds are listed order of decreasing water solubility, from left to right (Mackay *et al.*, 1992).

4.3 Mussel Contaminant Accumulation

4.3.1 Contaminants Spatial Pattern

Tables 9 and 10 summarize concentrations of arsenic, metals and PAHs in musssel tissues after their three week exposure to water and sediment along the Slag Dump shoreline. Unfortunately, cages could not be recovered at three of the locations, including the upstream control in Point aux Pins Bay. Therefore, comparisons are made to the pre-exposure (Balsam Lake) concentrations in the mussels.

Although mean concentrations of arsenic and some metals in *E. complanata* were higher after exposure at a few of the stations (e.g., Fig. 8), the majority of differences were not statistically significant ($p > 0.05$) from each other or from pre-exposure concentrations. Only the concentrations of lead at Station 123 (0.94 $mg.kg^{-1}$) and magnesium at Station 127-M (352 $mg.kg^{-1}$) were significantly higher ($p < 0.05$) than concentrations in mussels at the other stations (Table 9).

The spatial pattern of PAH bioavailability and hence, accumulation by the mussels differed from that of metals, with accumulated concentrations often being significantly higher ($p < 0.05$) than pre-exposure at the most easterly stations (i.e., beginning at Stations 198, 197 or 196 - see Table 10 and Fig. 9). For example, the mean Total PAHs content of Stations 196 (2698 μg.kg-1) and 195 (2361 μg.kg-1) mussels were significantly higher than at all other stations (see Table 10).

There was no significant difference (t-test and MANOVA-Tukeys HSD test; $p > 0.05$) between the mean concentrations of Total PAHs or individual compounds accumulated by mussels exposed only to water (at mid-depth) or to both sediment and water (on the bottom) at Stations 121 and 197 (Table 10 and Fig. 11). This indicates that, at least at these two stations, the primary exposure route of for filter-feeding aquatic organisms is aqueous. There was however, a significantly higher ($p < 0.05$) concentration of Total PAHs as well as the more water soluble PAHs (acenaphthene, acenaphthylene, anthracene, fluorene, naphthalene and phenanthrene - see Fig. 12) in mussels exposed to the sediment at Station 127, near the Algoma Slip entrance (Fig. 3). The reason(s) for this difference are presently unknown.

Mussel tissues tended to contain higher concentrations of the more water soluble and lower molecular weight PAHs (e.g., naphthalene), and very little if any of the lower solubility/higher molecular weight/higher K_{ow} compounds (e.g., benzo(g,h,i)perylene and dibenzo(a,h)anthracene), which were nevertheless present in the sediments (see Table 6). Of the 16 PAHs analyzed for, phenanthrene, naphthalene, fluoranthene and pyrene were, on average, the dominant compounds in mussel tissues (Fig. 10). This PAH abundance profile is similar to that observed during a 1985 biomonitoring study in the river (Kauss & Hamdy, 1991).

PAH accumulation by mussels may well be related to discrete inputs from the Slag Dump. During 1988-89, Total PAHs concentrations in shallow perimeter groundwater monitoring wells

Table 11. Comparison of 1985, 1987 and 1989 polycyclic aromatic hydrocarbons concentrations in caged mussels exposed along the Algoma Slag Dump shoreline. Concentrations in $\mu g.kg^{-1}$ (ppb), dry weight.

Station:	124			123		121			127	
Compound / Year:	'85	'87	'89	'85	'89	'85	'87	'89	'87	'89
Acenaphthene	1<W	34	--	0.9	15<T	1<W	36<T	8<W	188	104
Acenaphthylene	0.4	20	--	1<W	5<W	1<W	18<T	5<W	52<T	11<T
Anthracene	0.8	13	--	1	14<T	2	7<T	9<W	74<T	36
Benzo(a)anthracene	--	5<W	--	--	4<T	--	12<T	4<T	416	49
Benzo((b)fluoranthene	2<W	7<W	--	2<W	7<W	2<W	16<T	7<W	473	50
Benzo(k)fluoranthene	--	6<W	--	--	7<T	--	6<W	6<W	6<W	27
Benzo(g,h,i)perylene	1<W	6<W	--	1<W	6<W	1<W	6<W	6<W	10<T	6<W
Benzo(a)pyrene	1<W	8<W	--	1<W	8<W	1<W	8<W	8<W	123	10<T
Chrysene	2<W	7<T	--	2<W	11<T	2<W	17<T	11<T	346	64
Dibenzo(a,h)anthracene	1<W	7<W	--	1<W	7<W	1<W	7<W	7<W	7<W	7<W
Fluoranthene	13	39<T	--	21	26<T	5	46<T	19<T	230	170
Fluorene	0.4	87<T	--	12	30<T	1<W	87<T	7<T	256	141
Indeno(1,2,3-cd)pyrene	1<W	6<W	--	1<W	6<T	1<W	6<W	18<T	9<T	6<W
Naphthalene	45	105<T	--	17	26<T	86	95<T	29<T	444	417
Phenanthrene	2	133	--	8	137	0.8	95	39<T	161	420
Pyrene	9	31<T	--	12	16<T	3	53<T	14<T	202	138
Total of 16 PAHs	71	469	--	72	288	97	482	127	2984	1618

NOTES: "<T" = a measurable trace amount; interpret with caution.
"<W" = no measurable response (zero): less than reported value.
"–" = no data available; cages not recovered.

on the slag dump ranged between 0.7 and 61 $\mu g.l^{-1}$ (Berry-Spark & Tossell, 1990). The highest concentrations were found at wells in the vicinity of Station 203, with somewhat lower levels in wells near Stations 205, 196, 195 and 127 (see Fig. 3).

Correlation analysis on log-transformed replicate data showed that concentrations of most individual PAH compounds in mussels were significantly correlated ($r = 0.58$ to 1.00; $p < 0.05$) with each other and occasionally with lipid content, but only rarely with mercury levels (Appendix Tables C-8 to C10). Indeno(1,2,3-cd)pyrene concentrations did not correlate significantly with those of other PAHs, probably due to the high frequency of non-detects for this compound. Of the heavy metals, cadmium, magnesium, manganese and zinc concentrations were significantly correlated with each other ($r = 0.58$ to 0.83; $p < 0.05$). Tissue arsenic levels were not significantly correlated with any of the other contaminants analyzed for.

4.3.2 Contaminants Temporal Trends

Ministry biomonitoring studies for PAHs were also conducted in 1985 and 1987, using the same mussel species and methodology. PAH compound concentrations accumulated by with *Elliptio complanata* at Stations 124, 123, 121 and 127 in 1985, 1987 and 1989 are summarized in Table 11. Trends in PAH concentrations over the two or four year period were variable with regards to station location. For example, levels of Total PAHs at Leigh Bay stations (124 and 123) increased four- to nearly seven-fold between 1985 and 1987 and 1985 and 1989, respectively. At Station 121, concentrations were five-fold higher in 1987 than 1985, but were four-fold lower in 1989 than 1987. For all years, the greatest Total PAHs accumulation occurred at Station 127, although 1989 concentrations were about half those in 1987. These year-to-year fluctuations were also evident in the concentrations of individual PAHs (Table 11), and may be related to temporally varying concentrations of these PAHs (particularly the more water-soluble compounds) in the water filtered by the mussels. Such concentration differences may be related to changes in the magnitude of loadings (i.e., groundwater inflow, surface runoff) from the Slag Dump.

4.4 Mussel-Sediment Contaminant Relationships

There was a significant correlation between Total PAHs in mussels and their lipid content (although there was considerable scatter), but not between lipid-normalized concentrations in mussels and TOC-normalized sediment levels (Fig. 13). The average PAH compound profile in mussels also differed somewhat from that in sediments (cf. Figs. 7 and 10). This suggested that the mussel PAH concentrations are not directly related to the filtering out and ingestion of contaminated sediment particles. Rather, they are related to PAH concentrations in the water, which are perhaps also responsible for the elevated sediment PAH concentrations. An earlier biomonitoring study found no significant correlation between the concentrations of individual PAHs in mussels and in sediments (Kauss & Hamdy, 1991).

Concentrations of Total PAHs in the mussels were compared with those in the corresponding

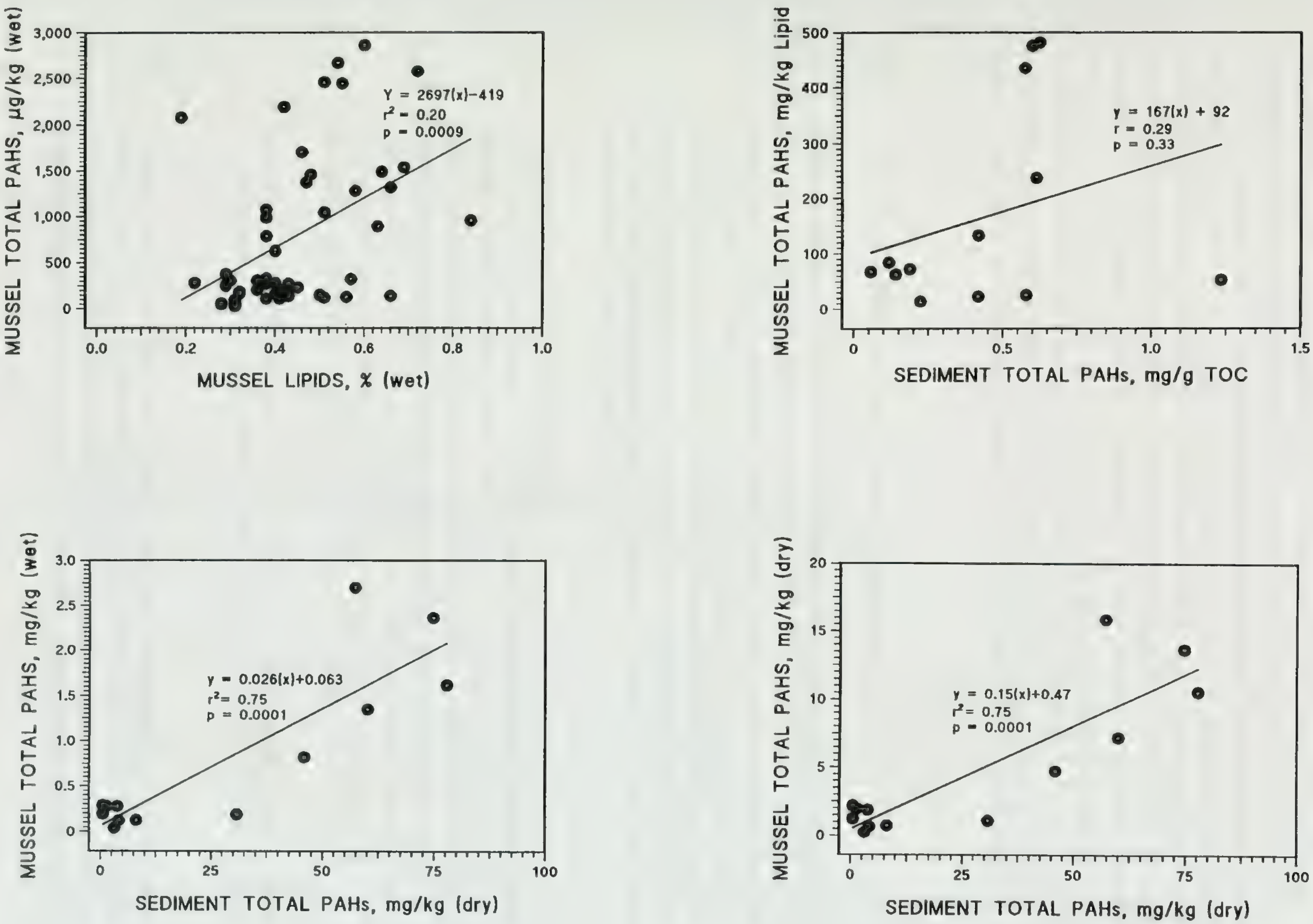

Figure 13. **Relationships between concentrations of Total PAHs in musssels and sediments.**

Table 12. Mussel-sediment PAH accumulation factors.
(BSAFs are on dry weight basis)

Station Number	Ace-naph-thene	Ace-naph-thylene	Anthra-cene	Benzo(a)-anthra-cene	Benzo(b)-fluoran-thene	Benzo(k)-fluoran-thene	Benzo(a)-pyrene	Chry-sene	Fluor-anthene	Fluor-ene	Indeno-(1,2,3-cd)pyrene	Naph-thalene	Phen-anthrene	Pyrene	Total of 16 PAHs
205	1.10	--	4.40	0.65	0.00	0.00	0.00	2.50	6.55	3.28	0.00	2.35	8.76	1.67	2.54
123	2.83	--	10.50	1.50	0.00	2.65	0.00	4.15	9.80	5.65	1.13	4.90	14.71	2.00	4.51
204	2.45	--	2.80	0.14	0.00	0.00	0.00	0.40	0.67	5.43	0.90	1.51	7.15	0.55	1.32
203	1.83	--	1.74	0.07	0.00	0.13	0.00	0.16	0.27	4.33	0.47	4.18	3.57	0.23	0.52
122	0.27	0.00	0.03	0.00	0.00	0.00	0.00	0.01	0.02	0.22	0.03	0.34	0.15	0.02	0.04
121	0.00	--	0.00	0.03	0.00	0.00	0.00	0.08	0.09	0.80	0.17	2.73	0.43	0.08	0.10
201	0.00	--	0.00	0.00	0.00	0.00	0.00	0.07	0.15	0.00	0.00	3.16	0.97	0.12	0.17
200	0.00	--	0.00	0.00	0.00	0.00	0.00	0.14	0.05	0.00	0.00	1.05	0.63	0.05	0.09
198	0.28	0.10	0.07	0.04	0.03	0.04	0.00	0.08	0.13	0.26	0.00	0.30	0.29	0.11	0.11
197	0.50	0.15	0.09	0.06	0.07	0.05	0.02	0.10	0.14	0.47	0.02	0.79	0.28	0.13	0.13
196	1.89	0.50	0.26	0.12	0.11	0.00	0.05	0.16	0.22	1.58	0.00	2.33	0.83	0.20	0.29
195	1.16	0.25	0.16	0.05	0.04	0.03	0.01	0.07	0.13	0.95	0.00	1.45	0.50	0.13	0.19
127	0.65	0.19	0.11	0.05	0.04	0.06	0.01	0.07	0.08	0.58	0.00	0.80	0.31	0.09	0.14

NOTE "--" indicates PAH not detected in either mussel or sediment, BCF could therefore not be calculated

sediments at each station to determine if there was any significant relationship. As shown by Figure 13, this relationship was equally positive and strong ($r^2 = 0.75$; $p = 0.0001$) whether the mussel concentrations were expressed on a wet weight, or a dry weight basis (using concentrations in mussels converted to a dry weight basis using the moisture content data in Table 9). Consequently, biota-sediment accumulation factors (BSAFs) were calculated on a dry weight basis (Table 12). The BSAFs were often less than 1 (indicating no bioaccumulation from sediments), particularly for PAHs of lower water solubility and greater tendency to partition onto organic carbon in the sediments, such as benzo(b&k)fluoranthenes, benzo(a)pyrene and indeno(1,2,3-cd)pyrene (Table 12). Bioavailability was, however suggested by the BSAFs (range: 1.1 to 14.7) for the more water soluble PAHs (i.e., acenaphthene, anthracene, fluoranthene, fluorene, naphthalene, phenanthrene and pyrene) at some of the Leigh Bay/west end of slag dump stations (numbers 205, 123, 204, 203). The maximum of this BSAF range is somewhat greater than the range (< 0.0001 to 8.96) reported from a 1985 study (Kauss & Hamdy, 1991).

5.0 CONCLUSIONS AND RECOMMENDATIONS

(i) Sediments at many of the 16 locations sampled around the Algoma Slag Dump shoreline contained concentrations of persistent contaminants - including arsenic, cyanide, heavy metals and polycyclic aromatic hydrocarbons (PAHs) - above levels at the upstream control station in Point aux Pins Bay. Concentrations of most contaminants were generally highest at stations located along the eastern half of the dump, adjacent to the St. Marys River and close to the Algoma Slip (i.e., Stations 199, 198, 197, 196, 195, 127), with the peak concentrations usually occurring at Station 199. This may be related to groundwater or runoff input(s) from the dump.

Concentrations of all 16 individual PAH compounds were significantly correlated with each other in the sediments, with TOC content, and with arsenic, copper, cyanide, lead, mercury, nickel and zinc levels. This suggests common source(s) of these contaminants. When normalized to TOC content, the highest arsenic, copper, cyanide, lead, mercury, nickel and zinc concentrations in sediments were at the southeastern end of Leigh Bay (Stations 205 and/or 123) and at the middle of the south shore (Station 199). The pattern for PAHs changed only slightly from the non-normalized concentrations (i.e., highest at the eastern end of the dump shoreline).

Recommendation: Based on information from this study, inputs from the dump should be identified and controlled to prevent continuing adverse impacts on the St. Marys River.

(ii) Arsenic, cadmium, chromium, copper, iron, lead, manganese, nickel, zinc and organic carbon (TOC) concentrations exceeded the respective Provincial Sediment Quality Guideline (PSQG) Lowest Effect Levels (LELs) at the majority of stations sampled. Arsenic, iron, manganese, zinc and TOC also exceeded their respective PSQG-Severe

Effect Levels (SELs) at some stations. Levels of cyanide were above the Provincial guideline for open water disposal of dredged material at most stations. Total PAH concentrations exceeded the PSQG-LEL of 4 $mg.kg^{-1}$ at nine of the 16 dump stations, with levels ranging from 4.2 $mg.kg^{-1}$ to 81.2 $mg.kg^{-1}$ in samples. Also, concentrations of all 12 of the individual PAH compounds for which guidelines are currently available were above their respective PSQG-LELs. Based on PSQG exceedences, sediments from some of the slag dump stations were "marginally" or "grossly polluted". Such sediments would have the potential to affect use by the more sensitive sediment-dwelling organisms (marginally polluted) or significantly affect use by the majority of organisms (grossly polluted).

<u>Recommendation:</u> *Future surficial sediment quality surveys around the Algoma Slag Dump should incorporate assessment of the status of associated benthic invertebrate communities and sediment bioassays utilizing laboratory test species.*

(iii) Trends in sediment contaminant concentrations at four stations sampled in both 1989 and an in 1987 were variable, depending both on station location and the specific contaminant. This may be due to the natural heterogeneity of sediments in this area or to changes in sediment quality due to physical factors, such as wind-induced currents, wakes or prop wash from large vessels approaching the nearby Algoma Slip, and ice scour.

<u>Recommendation:</u> *To obtain statistically valid information for the evaluation of long term contaminant trends in the sediments and hence, the efficacy of any remediation efforts, a subset of the stations sampled in 1989 should be periodically re-sampled (e.g., every 5 years or so), with replication.*

(iv) Although mean concentrations of arsenic and some heavy metals in mussels were higher at a few of the stations, these differences were in most instances not statistically significant from each other or from pre-exposure concentrations, indicating either that these elements are not biologically available to filter-feeding aquatic organisms or that the exposure period was not long enough.

<u>Recommendation:</u> *Future biological monitoring with caged mussels in this area should incorporate longer exposure periods (e.g., 3 months or longer) to determine if arsenic and heavy metals are biologically available to aquatic organisms.*

(v) Concentrations of PAHs were significantly higher at the most easterly stations (i.e., closer to the Algoma Slip), indicating greater biological availability and higher concentrations of PAHs in this area.. Mussel tissues tended to contain higher concentrations of the more water soluble PAHs (e.g., naphthalene), and very little if any of the lower solubility and higher molecular weight/higher octanol-water partition coefficient compounds (e.g.,

benzo(g,h,i)-perylene), which were nevertheless present in the sediments. This suggests that the more bioavailable PAHs are those which are more water soluble and present at higher concentrations. Of the 16 PAHs analyzed for, phenanthrene, naphthalene, fluoranthene and pyrene were on average, present at the highest concentrations in mussels. Concentrations of most individual PAH compounds were significantly and positively correlated with each other in the mussels and occasionally with lipid content, but only rarely with mercury levels and not at all with arsenic or the other heavy metals. This suggests a common source of the PAHs.

Recommendation: *At locations with significantly higher PAH concentrations in mussels inputs from the dump should be identified and controlled to prevent continuing impacts on the St. Marys River.*

(vi) Comparison to results for four of the 1989 stations also used in 1987 and 1985 indicated year-to-year fluctuations in the concentrations of individual PAHs. These may be related to temporally varying concentrations of these compounds (particularly the more water-soluble compounds) in the water filtered by the mussels. Such concentration differences may be related to temporal variability in the magnitude of inputs (i.e., loadings) from the Slag Dump.

(vi) Concentrations of Total PAHs in the mussels correlated positively with those in the corresponding sediments at the sampling/biomonitoring stations. Calculated mussel-sediment bioaccumulation factors (BSAFs) for individual PAHs and stations were often less than 1 (indicating no bioaccumulation from sediments), particularly for compounds of lower water solubility, such as benzo(b&k)fluoranthenes, benzo(a)pyrene and indeno(1,2,3-cd)pyrene. Bioaccumulation was, however suggested by the BSAFs (range: 1.1 to 14.7) for the more water soluble PAHs (i.e., acenaphthene, anthracene, fluoranthene, fluorene, naphthalene, phenanthrene and pyrene) at some of the Leigh Bay/west end of slag dump stations. There was no significant difference between PAH levels in mussels exposed only to water (mid-depth) or to both sediment and water (on the bottom) at Stations 121, 197 and 127.

There was a significant correlation between Total PAHs in mussels and their lipid content, but not between lipid-normalized concentrations in mussels and TOC-normalized sediment levels. This suggests that the mussel PAH concentrations are not directly related to the filtering out and ingestion of sediment particles. Rather, they are related to PAH concentrations in the water, which are perhaps also responsible for the elevated sediment PAH concentrations.

6.0 REFERENCES

Arthur, A. and P.B. Kauss, 1999. Sediment and Benthic Community Assessment of the St. Marys River - 1992. Integrated Explorations (Guelph) and Ontario Ministry of the Environment report for the Water Monitoring Section, Environmental Monitoring and Reporting Branch, OMOE. Etobicoke, Ontario. 100 pp.

Berry-Spark, K. and R. Tossell, 1990. Slag Disposal Site Investigation at Algoma Steel Corporation. Volume I of II. Report by Beak Consultants Limited in association with Terraqua Investigations Ltd. and D.L. Lee of Atomic Energy of Canada Ltd. for the Ontario Ministry of the Environment, Sarnia.

Burt, A. J., D. R. Hart and P. M. McKee, 1988. Benthic Invertebrate Survey of the St. Marys River, 1985. Volume 1 - Main Report. Report by Beak Consultants Limited for the Great Lakes Section, Water Resources Branch, Ontario Ministry of the Environment, Toronto, Ontario. 57 pp. + appendices.

Conestoga-Rovers and Associates Limited, 1988. Phase II Hydrogeologic Investigation. Report for Algoma Steel Corporation, Ltd., Sault Ste. Marie. December, 1988. Waterloo, Ontario. 57 pp. + figures and appendices.

Gartner Lee Ltd., 1988. Hydrogeologic Study Domtar Coal Tar Plant, Sault Ste. Marie. Interim Report on Phase II Studies. Report GLL 87-300 for Domtar Inc., April, 1988. Markham, Ontario. 8 pp. + figures and tables.

Geocon, 1983. Hydrogeological Investigation, Slag Dump Area. Report V8508 for the Algoma Steel Corporation Limited. February 15, 1983. Toronto, Ontario.

Kauss, P.B. and R.V. Angelow, 1988. Evaluation of Biological Monitoring Studies with the Freshwater Mussel *Elliptio complanata* in the Niagara River and Selected Ontario Tributaries during 1980 and 1981. Ontario Ministry of the Environment, Water Resources Branch file report. Toronto, Ontario. 67 pp.

Kauss, P.B. and Y.S. Hamdy, 1985. Biological monitoring of organochlorine contaminants in the St. Clair and Detroit Rivers using introduced clams, *Elliptio complanata*. J. Great Lakes Res., **11**(3): 247-263.

Kauss, P. B. and Y. S. Hamdy, 1991. Polycyclic aromatic hydrocarbons in surficial sediments and caged mussels of the St. Marys River, 1985. Hydrobiologia, **219**: 37-62.

Kauss, P.B. and P.C. Nettleton, 1999. Impact of Sault Ste. Marie East End Wastewater Treatment Plant Discharge on Lake George Channel Waters. Ontario Ministry of the Environment, Water Monitoring Section and Environmental Modelling and Emissions Inventory Section technical report. Etobicoke, Ontario. 58 pp.

Lee, D.R. and S.J. Welch, 1988. Research and Development of Methods for Locating and Estimating Contaminant Loading Via Groundwater Entering the St. Marys River. Chalk River Laboratories report for the Ontario Ministry of the Environment, Detroit, St. Clair and St. Marys River Improvement Team, Sarnia, Ontario. Chalk River, Ontario.

Mackay, D., W.Y. Shiu and K.C. Ma, 1992. Illustrated Handbook of Physical-Chemical Properties and Environmental Fate for Organic Chemicals. Volume II. Polynuclear Aromatic Hydrocarbons, Polychlorinated Dioxins, and Dibenzofurans. Lewis Publishers, Ann Arbor, Michigan.

McKee, P. M., A. J. Burt and D. R. Hart, 1984. Benthic Invertebrate and Sediment Survey of the St. Marys River, 1983. Report by Beak Consultants for the Great Lakes Section, Water Resources Branch, Ontario Ministry of the Environment, Toronto, Ontario.

OMOE (Ontario Ministry of the Environment), 1983. Handbook of Analytical Methods for Environmental Samples. Laboratory Services and Applied Research Branch, Toronto, Ontario.

OMOE (______________________________), 1984. Water Management - Goals, Policies, Objectives and Implementation Procedures of the Ministry of the Environment. November 1978, revised May 1984. Toronto, Ontario. 70 pp.

OMOE (______________________________), 1985. Hamilton Harbour Technical Summary and General Management Options. Great Lakes Section, Water Resources Branch, Toronto, Ontario. 125 pp.

OMOE (______________________________), 1987. Environment Ministry Finds Coal Tar in Sault Ste. Marie Area. News Release, June 29. Toronto, Ontario. 3 pp.

OMOE (______________________________), 1989a. A Guide to the Collection and Submission of Samples for Laboratory Analysis. 6th edition. Laboratory Services Branch. Toronto, Ontario, 81 pp.

OMOE (______________________________), 1989b. The Determination of Mercury in Soils, Sediments and Vegetation by Cold Vapour-Atomic Absorption Spectrophotometry (CV-AAS). Laboratory Services Branch. Etobicoke, Ontario.

OMOE (______________________________), 1992. The St. Marys River Area of Concern Environmental Conditions and Problem Definitions Remedial Action Plan Stage I. Ontario Ministry of the Environment, Detroit/St. Clair/St. Marys River Project, and the Michigan Department of Natural Resources, Surface Water Quality Division, Great Lakes and Environmental Assessment Section. 333 pp.

OMOEE (Ontario Ministry of Environment and Energy), 1994. Water Management Policies, Guidelines, Provincial Water Quality Objectives of the Ministry of Environment and Energy. July, 1994. Toronto, Ontario. 21 pp. + table + appendix.

Persaud, D. and W. D. Wilkins, 1976. Evaluating Construction Activities Impacting on Water Resource. Water Resources Branch, Ontario Ministry of the Environment report.

Persaud, D., R. Jaagumagi and A. Hayton, 1993. Guidelines for the Protection and Management of Aquatic Sediment Quality in Ontario. Water Resources Branch, Ontario Ministry of Environment and Energy report. 24 pp. + figures.

Pope, R. J. and P.B. Kauss, 1995. Algoma Slip Sediment Quality and Benthic Invertebrate Community Assessment. Tarandus Associates Limited (Brampton) and Ontario Ministry of Environment Energy report for the Surface Water Section, Environmental Monitoring and Reporting Branch, OMOEE. Etobicoke, Ontario. 65 pp.

UGLCCS (Upper Great Lakes Connecting Channels Study Management Committee), 1989. Final Report of the Upper Great Lakes Connecting Channels Study. Volume II. Environment Canada, United States Environmental Protection Agency, Michigan Department of Natural Resources, Ontario Ministry of the Environment, National Oceanographic and Atmospheric Administration, U.S. States Fish and Wildlife Service, U.S. Army Corps of Engineers and Detroit Water and Sewerage Department, December, 1988. 591 pp. + appendices.

Wager, W., P. Kauss and D. Persaud, 1987. Presence of Coal Tar-Like Waste in Bennett and Spring Creeks, Sault Ste. Marie. June 24 Memorandum to G. LaHaye, Sault Ste. Marie District Officer, Ontario Ministry of the Environment. 2 pp.

APPENDIX A

1987 Algoma Slag Dump Sediment Quality Data

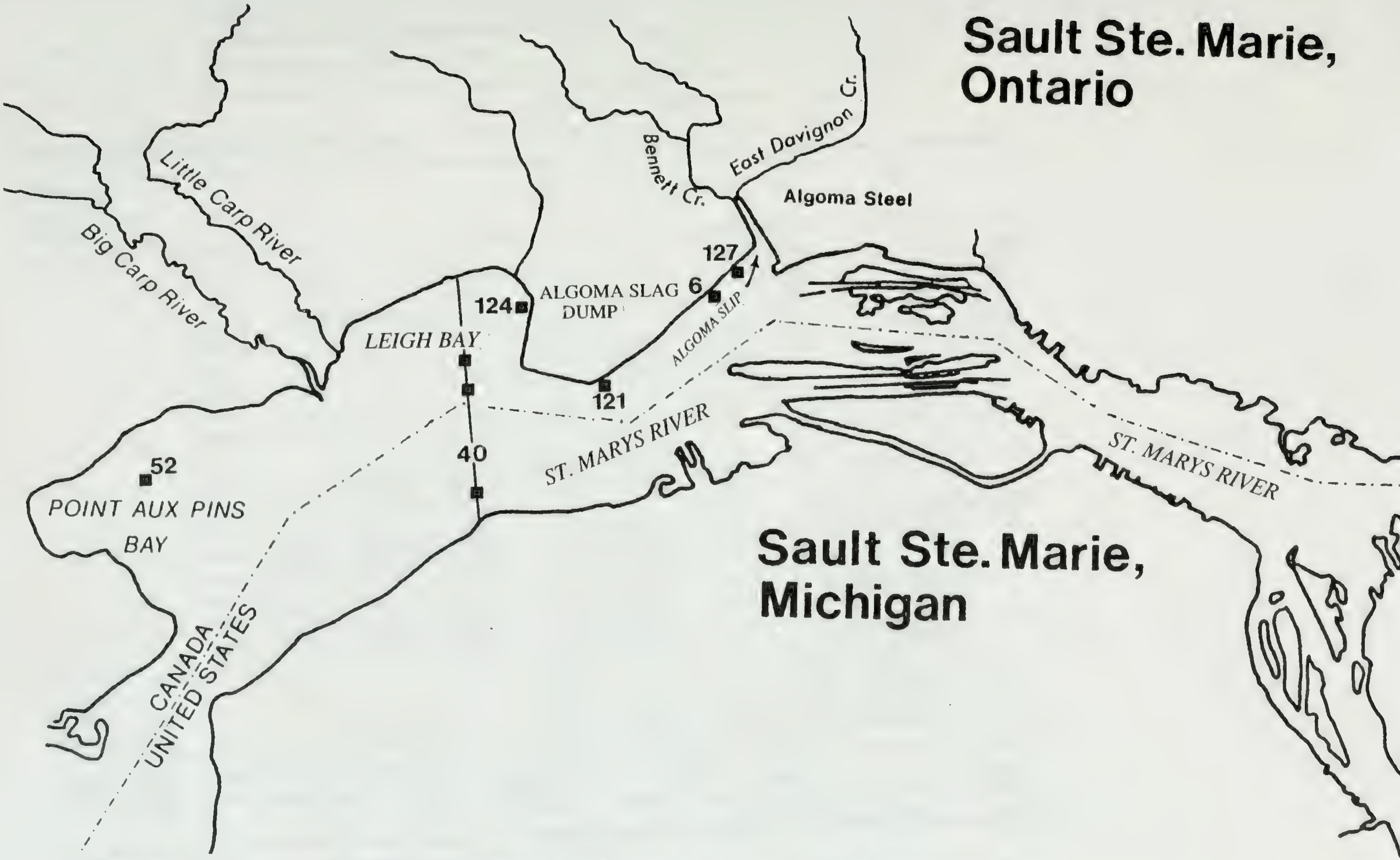

Figure A-1. Location of 1987 OMOE sampling locations in the vicinity of the Algoma Slag Dump.

Table A-1. Physical characteristics, organic carbon and solvent extractables concentrations in 1987 surficial sediments.

Concentration units as noted: % = percent; $g.kg^{-1}$ = ppth; $mg.kg^{-1}$ = ppm. All results except for density are on dry weight basis.

Station Number	Distance from CDN Shore, m.	Sample Date	Very Coarse Sand 2000->1000 um %	Sand 999->62 um %	Silt & Clay <62-0.17 um %	Moisture %	Field Density $g.cm^{-3}$	Residue, total loss on Ignition $g.kg^{-1}$	Organic Carbon, total $g.kg^{-1}$	Solvent Extractables $mg.kg^{-1}$
Pointe aux Pins Bay										
52	500	87/05/15	1.8	50.8	47.4	55	1.39	68	28	1260
Algoma Slag Dump										
40	200	87/05/17	0.6	47.9	51.5	29	1.82	20	13	1000
40	1300	87/05/15	0.6	40.6	58.8	54	1.46	38	21	833
40	1830	87/05/15	1.5	68.6	29.9	--	--	12	8.5	900
"	"	87/09/25	0.0	58.9	42.9	29	1.80	16	13	2154
124	140	87/05/15	0.4	29.4	70.2	28	1.64	42	22	651
121	40	87/05/17	2.2	52.8	45.0	--	--	24	22	5445
"	"	87/09/19	2.2	34.1	63.7	38	1.64	23	14	1896
6	50	87/05/17	0.5	28.4	71.1	--	--	70	**112**	2890
"	"	87/09/19	0.5	24.6	74.9	48	1.44	80	**100**	10576
127	70	87/05/17	1.7	44.0	54.3	--	--	93	**148**	2532
"	"	87/09/19	0.4	51.1	48.5	39	1.60	77	**140**	3799
PSQG-LEL					--	--	--	--	10	--
PSQG-SEL					--	--	--	--	100	--
OWDMDG					--	--	--	60	--	1500

NOTE: underlined value in shaded cell exceeds PSQ-LEL guideline or OWDMD guideline; bolded value exceeds PSQ-SEL guideline

Table A-2. Metal concentrations in 1987 surficial sediments.

All concentrations in $mg.kg^{-1}$ (ppm), dry weight.

Station Number	Distance from CDN shore, m	Sample Date	Cadmium	Chromium	Copper	Iron	Lead	Magnesium	Manganese	Nickel	Zinc
Pointe aux Pins Bay:											
52	500	87/05/15	0.50	10	12	5400	24.0	970	55	4.2	24
Algoma Slag Dump											
40	200	87/05/17	0.43	22	17	11000	12.0	2300	130	7.4	30
40	1300	87/05/15	1.00	26	30	14000	31.0	3500	140	13	55
40	1830	87/05/15	0.24	14	9.2	8720	45.0	2000	104	6.0	21
"	"	87/09/25	0.41	17	11	10040	11.0	2060	109	6.1	25
124	140	87/05/15	0.44	28	16	18000	16.0	4100	350	12	73
121	40	87/05/17	0.54	73	20	23500	21.0	12000	4050	11	52
"	"	87/09/19	0.61	67	19	19800	15.8	5400	2440	8.8	47
6	50	87/05/17	1.25	35	40	**51333**	87.0	5833	975	20	420
"	"	87/09/19	1.32	35	38	**47600**	81.0	5420	862	14	394
127	70	87/05/17	1.18	31	35	**53000**	65.0	6000	1040	19	314
"	"	87/09/19	0.91	31	31	**41800**	46.0	5040	840	12	252
PSQG-LEL:			0.6	26	16	20000	31	—	460	16	120
PSQG-SEL:			10	110	110	40000	250	—	1100	75	820
OWDMDG:			1	25	25	10000	50	—	—	25	100

NOTES: blank or "--" indicates that data is not available for this parameter or sample

underlined value in shaded cell exceeds PSQ-LEL guideline; bolded value exceeds PSQ-SEL guideline

Table A-3. Polycyclic aromatic hydrocarbon concentrations in 1987 surficial sediments.

All concentrations in mg.kg^{-1} (ppm), dry weight.

Station Number	Distance from CDN shore, m	Sample Date	Ace-naph-thene	Ace-naph-thylene	Anthra-cene	Benzo(a)-anthra-cene	Benzo(b)-fluoran-thene	Benzo(k)-fluoran-thene	Benzo-(g,h,i)-perylyne	Benzo(a)-pyrene	Chry-sene	Dibenzo-(a,h)an-thracene	Fluor-anthene	Fluor-ene	Indeno-(1,2,3-cd)pyrene	Naph-thalene	Phen-anthrene	Pyrene	Total of 16 PAHs
Pointe aux Pins Bay																			
52	500	87/05/15	0.04 <T	0.04 <T	0.01 <T	0.02 <T	0.06 <T	0.02 <T	0.04 <T	0.04 <T	0.02 <T	0.04 <T	0.04	0.04 <T	0.04 <T	0.04 <T	0.07 <T	0.06 <T	0.62
Algoma Slag Dump																			
40	200	87/05/17	0.04 <T	0.04 <T	0.01 <T	0.03	0.06	0.02	0.04	0.04	0.04	0.04 <T	0.06	0.04 <T	0.05	0.04 <T	0.07 <T	0.06 <T	0.68
40	1300	87/05/15	0.04	0.04	0.09	0.22	0.19	0.19	0.11	0.19	0.21	0.04	0.45	0.04	0.12	0.09	0.22	0.37	2.61
40	1830	87/05/15	0.04 <T	0.04 <T	0.01 <T	0.02 <T	0.06 <T	0.02 <T	0.04 <T	0.04 <T	0.02 <T	0.04 <T	0.03	0.04 <T	0.04 <T	0.40 <T	0.07 <T	0.06 <T	0.97
"	"	87/09/25	0.06	0.06	0.09	0.27	0.36	0.18	0.17	0.25	0.25	0.08	0.53	0.08	0.18	0.18	0.34	0.45	3.53
124	140	87/05/15	0.04	0.04	0.01	0.04	0.06	0.02	0.04	0.04	0.03	0.04	0.09	0.04	0.04 <T	0.04	0.07	0.07	0.71
121	40	87/05/17	0.23	0.18	0.66	2.60	3.40	3.40	3.18	3.54	3.42	0.52	4.80	0.20	3.39	0.46	2.11	4.37	36.46
"		87/09/19	0.04 <T	0.05 <T	0.02	0.09	0.16	0.08	0.07	0.12	0.10	0.04 <T	0.21	0.04 <T	0.09	0.04 <T	0.08	0.19	1.42
6	50	87/05/17	0.31	0.15	0.82	2.12	1.62	1.62	0.69	1.26	1.79	0.15	3.86	0.46	0.59	1.14	2.57	2.95	22.13
"		87/09/19	0.12	0.09	0.37	1.05	1.09	0.42	0.43	0.77	1.30	0.18	2.26	0.18	0.46	0.31	1.22	1.77	12.02
127	70	87/05/17	0.65	0.31	1.42	3.49	2.43	2.43	1.19	2.11	3.11	0.24	6.35	1.03	1.13	1.14	5.34	4.91	37.33
"	"	87/09/19	0.71	0.43	2.45	5.22	4.87	2.00	1.75	3.60	6.17	0.43	11.72	1.20	1.80	1.80	7.07	6.67	57.89
PSQG-LEL			--	--	0.22	0.32	--	0.24	0.17	0.37	0.34	0.06	0.75	0.19	0.20	--	0.56	0.49	4
PSQG-SEL			--	--	370	1480	--	1340	320	1440	460	130	1020	160	320	--	950	850	10000
OWDMDG:			--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

NOTES: blank or "--" indicates that data is not available for this parameter or sample
"<T" = a measurable trace amount: interpret with caution
underlined value in shaded cell exceeds PSQ-LEL guideline
PSQG-SEL isd TOC-based

Table A-4. Phenolic compound concentrations in 1987 surficial sediments.

All concentrations in ug.kg^{-1} (ppb), dry weight.

Station Number	Distance from CDN shore, m	Sample Date	Phenol	m-Cresol	o-Cresol	p-Cresol
Pointe aux Pins Bay						
52	500	87/05/15	50 <W	50 <W	60 UIN	1000
Algoma Slag Dump						
40-200	200	87/05/17	50 <W.	50 <W	50 <W	365
40-1300	1300	87/05/15	50 <W	50 <W	50 <W	225
40 1830	1830	87/05/15	50 <W	50 <W	50 <W	383
"	"	87/09/25	--	--	--	--
124	140	87/05/17	50 <W	50 <W	50 <W	140
121	40	87/05/17	70	50 <W	60	50
"	"	87/09/19	--	--	--	--
6	50	87/05/17	95	50 <W	50 <W	1050
"	"	87/09/19	--	--	--	--
127	70	87/05/17	160	50 <W	50 <W	850
"	"	87/09/19	--	--	--	--
PSQG-LEL:			--	--	--	--
PSQG-SEL:			--	--	--	--
OWDMDG:			--	--	--	--

NOTES: blank or "--" indicates that data is not available for this parameter or sample

"<W" = no measurable response (zero): less than reported value

APPENDIX B

1987 Bennett Creek Sediment Core Data

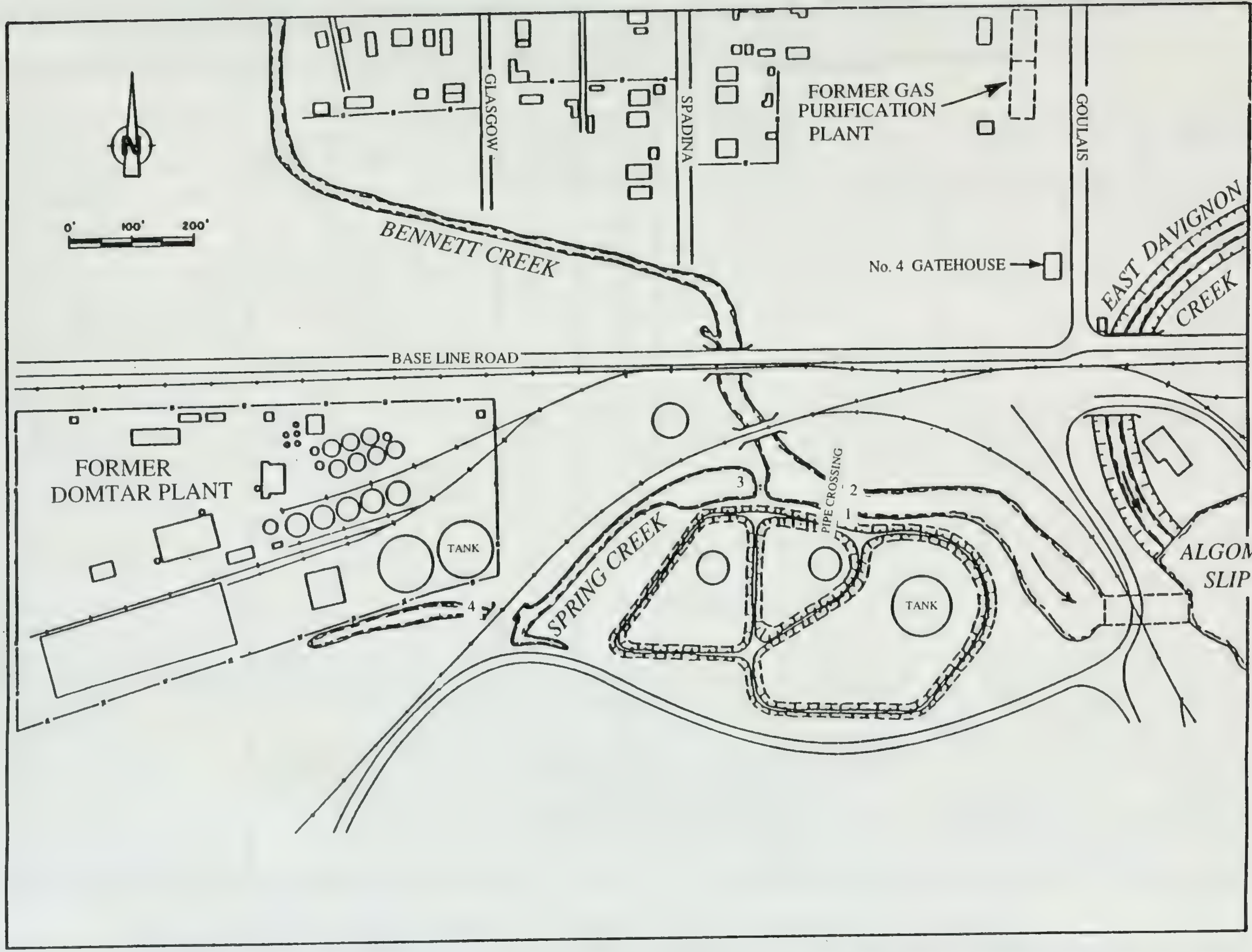

Figure B-1. Location of 1987 OMOE Bennett Creek sampling locations. Map adapted from Conestoga Rovers and Associates (1988).

Table B-1. Concentrations of contaminants in Bennett Creek and Spring Creek sediment cores relative to coal tar and creosote, 1987. PAH concentrations are approximate, relative to the d_{10}-phenanthrene external standard.

Contaminant	Units (dry weight)	Sampling Location											
		Algoma Steel Corp. coal tar	Domtar Inc. creosote	1		2		3				4	
				Bennett Cr. at pipe crossing, 3 metres from south shore		*Bennett Cr. at pipe crossing,6 metres from north shore*		*Spring Cr.,15 m. west of Bennett Cr., 4 metres from shore*				*Spring Cr., next to Domtar tanks*	
				surface "oil" layer	10-30 cm core section	0-12.5 cm core section	12.5-22.5 cm core section	0-12.5 cm core section	12.5-22.5 cm core section	22.5-33 cm core section	22.5-58 cm core section	0-7.5 cm core section	7.5-35 cm core section
	Sample No.	16285	16286	50681	50683	50684	50685	50689	50690	50691	50692	50693	50694
Cadmium	$mg.kg^{-1}$	--	--	--	--	0.98	--	--	--	--	--	--	--
Chromium	"	--	--	--	--	31	--	--	--	--	--	--	--
Iron	"	--	--	--	--	1400	--	--	--	--	--	--	--
Lead	"	--	--	--	--	28	--	--	--	--	--	--	--
Magnesium	"	--	--	--	--	3700	--	--	--	--	--	--	--
Manganese	"	--	--	--	--	960	--	--	--	--	--	--	--
Nickel	"	--	--	--	--	10	--	--	--	--	--	--	--
Zinc	"	--	--	--	--	320	--	--	--	--	--	--	--
Total Organic Carbon	$g.kg^{-1}$	--	--	--	--	45	--	--	--	--	--	--	--
Solvent Extractables	$mg.kg^{-1}$	--	--	--	91300	4800	23400	28900	69700	--	71000	4040	30600
Polycyclic Aromatic Hydrocarbons													
Acenaphthene	$mg.kg^{-1}$	0.1	13	3.7	0.62	--	0.14	1.3	8.2	12	2.9	0.25	4
Acenaphthylene	"	2.8	0.06	11	0.014	--	nd	nd	0.2	0.2	nd	nd	0.055
Anthracene	"	--	--	nd	0.34	--	0.051	0.74	6.7	15	2.1	0.62	2.9
Benzo(a)anthracene	"	1	1.4	6.8	0.2	--	0.063	0.32	2.5	3.1	0.85	0.15	0.43
Benzo Fluorenes	"	0.7	1.76	3.80[2]	0.24[2]	--	0.92[2]	0.50[2]	2.40[2]	3.80[2]	0.89[2]	0.14[2]	1.60[2]
Benzo(b/k)fluoranthene	"	1.7	0.83	8.2	0.21	--	0.032	0.5	2.9	4.8	1.7	0.18	0.89
Benzo(j)fluoranthene	"	nd	nd	1.1	nd	--	nd	nd	0.2	0.32	0.11	0.006	nd
Benzo(g,h,i)fluoranthene	"	nd	0.15	0.76	0.034	--	nd	nd	0.22	0.72	0.27	0.054	nd
Benzo(a)pyrene	$mg.kg^{-1}$	0.78	0.32	4.8	0.079	--	0.049	0.37	1.4	2	0.87	0.09	0.64
Benzo(e)pyrene	"	0.4	0.18	3	0.076	--	0.027	0.18	0.9	1.2	0.47	0.05	0.14

Contaminant	Units (dry weight)	Algoma Steel Corp. coal tar	Domtar Inc. creosote	1 — *Bennett Cr. at pipe crossing, 3 metres from south shore*		2 — *Bennett Cr. at pipe crossing, 6 metres from north shore*		3 — *Spring Cr., 15 m. west of Bennett Cr., 4 metres from shore*				4 — *Spring Cr., next to Domtar tanks*	
				surface "oil" layer	10-30 cm core section	0-12.5 cm core section	12.5-22.5 cm core section	0-12.5 cm core section	12.5-22.5 cm core section	22.5-33 cm core section	22.5-58 cm core section	0-7.5 cm core section	7.5-35 cm core section
	Sample No.	16285	16286	50681	50683	50684	50685	50689	50690	50691	50692	50693	50694
Chrysene	$mg.kg^{-1}$	1	1.4	5.4	0.38	--	0.12	0.35	2.4	5.9	1.9	0.21	2.7
4H-Cyclopenta(d,e,f)phenanthrene	"	0.68	2.5	4.1	0.34	--	0.1		2.5	2.1	1	0.26	1.8
Benzo(g,h,i)perylene/Dibenzo(a,h)anthra	"	0.5	0.11	2.7	nd	--	nd	nd	0.76	1.2	0.35	0.017	0.11
Fluoranthene	"	3.2	13.1	24	1.6	--	0.66	2.6	12	15	4.6	1.5	6.6
Fluorene	"	1.5	7	8.8	0.66	--	0.12	0.98	7.1	11	2.4	0.26	2.9
Indane	"	nd	0.96	nd	nd	--	nd	nd	nd	0.94	0.2	nd	nd
Indene	"	0.6	0.86	1.6	nd	--	nd	nd	nd	0.3	nd	nd	nd
Indeno(1,2,3-cd)pyrene	"	0.44	0.06	2.7	nd	--	nd	nd	0.72	0.86	0.29	nd	0.13
Naphthalene	"	15	32.2	75	1.2	--	nd	1.9	32	28	6.6	0.16	8.2
Perylene	"	0.17	0.07	1.6	0.092	--	nd	nd	0.43	0.38	0.39	nd	nd
Phenanthrene/Anthracene	"	6.1	27.9	38	3	--	0.87	3.9	23	29	6.6	2.6	11
Pyrene	"	2.3	11	17	1.3	--	0.54	2.2	11	13	4.2	1.1	5.8
Triphenylene/Naphthacene	"	0.25	0.33	nd	nd	--	nd	nd	nd	nd	nd	nd	nd
Alkylated PAHs:													
C_1(methyl)-Benz(a)anthracene	$mg.kg^{-1}$	0.6	0.2	nd	nd	--	nd	nd	0.36	5.90 [2]	0.13	nd	nd
C_2-(alkyl)-Fluoranthene/C_2-(alkyl) Pyrene	"	nd	0.1	nd	nd	--	nd	nd	0.12	0.67 [2]	0.33 [2]	nd	0.12
C_1(methyl)-Fluoranthenes/C_1-(methyl)	"	nd	1.1	1.30 [2]	0.10 [2]	--	nd	0.29 [2]	1.40 [2]	0.54 [2]	0.77 [2]	0.094	0.29 [2]
C_1(methyl)-Fluorenes	"	nd	0.66	nd	0.041	--	0.092 [2]	nd	0.6	0.97 [3]	0.15	nd	0.56 [4]
C_1(methyl)-Naphthalenes	"	2.2	6.1	7.30 [2]	0.26 [2]	--	nd	0.61	9.3	10	1.6	0.14	3.20 [2]
C_2(alkyl)-Naphthalene	"	0.2	1.8	1.00 [2]	0.05 [2]	--	nd	0.24 [4]	2.70 [5]	3.50 [5]	0.6	nd	1.00 [4]
C_3(alkyl)-Naphthalene	"	nd	1.36	nd	nd	--	nd	nd	0.15 [2]	0.40 [2]	nd	nd	0.066
C_1(phenyl)-Naphthalene	"	nd	1	0.37	0.058	--	0.051	nd	0.70 [2]	0.79	0.15	0.061 [3]	0.44 [2]
C_1(methyl)-Phenanthrenes/C_1(methyl)-	"	0.32	27.2	1.70 [2]	0.15 [2]	--	0.082 [3]	0.30 [2]	1.90 [3]	4.40 [3]	0.70 [3]	0.20 [3]	1.1
4H-cyclopenta(d,e,f)Phenanthrene	$mg.kg^{-1}$	0.68	2.5	4.1	0.34	--	0.1	0.64	2.5	2.1	1	0.26	1.8

Contaminant	Units (dry weight)	Sampling Location											
		Algoma Steel Corp. coal tar	Domtar Inc. creosote	1		2		3				4	
				Bennett Cr. at pipe crossing, 3 metres from south shore		*Bennett Cr. at pipe crossing,6 metres from north shore*		*Spring Cr.,15 m. west of Bennett Cr., 4 metres from shore*				*Spring Cr., next to Domtar tanks*	
				surface "oil" layer	10-30 cm core section	0-12.5 cm core section	12.5-22.5 cm core section	0-12.5 cm core section	12.5-22.5 cm core section	22.5-33 cm core section	22.5-58 cm core section	0-7.5 cm core section	7.5-35 cm core section
	Sample No.	16285	16286	50681	50683	50684	50685	50689	50690	50691	50692	50693	50694
Nitrogen-containing PAHs:													
Acridine	$mg.kg^{-1}$	nd	0.35	nd	nd	--	nd	nd	0.15	0.24	0.075	nd	nd
Carbazole	"	0.03	1.4	1.2	0.092	--	nd	0.099	1.8	5.3	0.53	0.031	0.34
C_1(methyl)-Carbonitrile	"	nd	0.1	nd	nd	–	nd	nd	nd	nd	nd	nd	nd
Fluoranthene amine	"	nd	0.07	nd	nd	--	nd	nd	0.36 [2]	0.89	0.15	nd	0.081
Anthracene Carbonitriles	"	nd	0.5	nd	nd	–	nd	nd	nd	nd	nd	nd	nd
Naphthalene Carbonitriles	"	nd	0.26	nd	0.01	--	nd	0.029	0.18	0.24	0.056	nd	nd
9H-Fluorene-9-Carbonitrile	"	nd	0.1	nd	nd	--	nd	nd	nd	nd	nd	nd	nd
Quinoline/Isoquinoline	"	nd	0.88	nd	nd	–	nd	nd	nd	nd	nd	nd	nd
C_1(methyl)-Quiniline/C_1(methyl)-	"	nd	0.08	nd	nd	–	nd	nd	nd	nd	nd	nd	nd
Oxygen-containing PAHs:													
C_1(methyl)-Benzofuran	$mg.kg^{-1}$	0.05	nd	nd	nd	--	nd	nd	nd	nd	nd	nd	nd
Dibenzofuran	"	0.9	5	3.8	0.3	--	0.024	0.45	4.5	5.7	1.1	0.14	1.6
C_1(methyl)-Dibenzofuran	"	0.26	1.2	1.00 [2]	0.058 [2]	--	0.019	0.063	1.30 [2]	1.90 [2]	0.30 [2]	0.084	0.34 [2]
Benzo(b)naphtho(2,3-d)furan	"	0.07	0.24	0.26	nd	--	nd	nd	0.24	0.32	0.082	nd	0.089
Dihydro Phenanthrene/Dihydro	"	nd	1.1	nd	nd	--	nd	nd	nd	nd	nd	nd	nd
Tetrahydro Phenanthrene/Tetrahydro	"	nd	0.3	nd	nd	--	nd	nd	nd	nd	nd	nd	nd
Sulphur-containing PAHs:													
Benzo(b)naphtho(1,2-d)thiophene	$mg.kg^{-1}$	nd	0.75	nd	0.05	--	nd	0.11	0.36	0.84	0.1	nd	nd
Benzothiophene	"	nd	1	nd	nd	--	nd	nd	0.33	0.64	nd	nd	nd
C_1(methyl)-Benzo(b)thiophene	"	nd	0.75	nd	nd	--	nd	nd	nd	nd	nd	nd	nd
Dibenzothiophene	"	0.2	1.4	1	0.13	--	0.022	0.16	0.59	1.6	0.25	0.054	0.4

Contaminant	Units (dry weight)	Sampling Location											
				1		2		3				4	
		Algoma Steel Corp. coal tar	Domtar Inc. creosote	*Bennett Cr. at pipe crossing, 3 metres from south shore*		*Bennett Cr. at pipe crossing,6 metres from north shore*		*Spring Cr.,15 m. west of Bennett Cr., 4 metres from shore*				*Spring Cr., next to Domtar tanks*	
				surface "oil" layer	10-30 cm core section	0-12.5 cm core section	12.5-22.5 cm core section	0-12.5 cm core section	12.5-22.5 cm core section	22.5-33 cm core section	22.5-58 cm core section	0-7.5 cm core section	7.5-35 cm core section
	Sample No.	16285	16286	50681	50683	50684	50685	50689	50690	50691	50692	50693	50694
Miscellaneous:													
Phenols	$mg.kg^{-1}$	nd	0.13	nd	nd	--	nd	nd	nd	nd	nd	nd	nd
Cresols	"	0.12	nd	nd	nd	--	nd	nd	nd	nd	nd	nd	nd
Xylenols	"	nd	0.06	nd	nd	--	nd	nd	nd	nd	nd	nd	nd
Biphenyl	"	0.16	1.1	0.57	0.066	--	nd	0.088	1.1	1.6	0.23	nd	0.5
C_1(methyl)-Biphenyls	"	nd	0.13	nd	nd	–	nd	nd	nd	nd	nd	nd	nd
C_2(alkyl)-Biphenyls	"	nd	0.18	nd	nd	–	nd	nd	nd	nd	nd	nd	nd
Polychlorinated Dibenzo-p-dioxins & Dibenzofurans:													
2,3,7,8-TetraCDD	$ng.kg^{-1}$	--	--	nd (30)	--	--	nd (40)	--	--	nd (50)	--	--	--
TetraCDD	"	--	--	nd (30)	--	--	nd (40)	--	--	nd (50)	--	--	--
PentaCDD	"	--	--	nd (40)	--	--	nd (40)	--	--	nd (80)	--	--	--
HexaCDD	"	--	--	nd (70)	--	--	nd (10)	--	--	nd (100)	--	--	--
HeptaCDD	"	--	--	nd (40)	--	--	98^{2}	--	--	nd (60)	--	--	--
OctaCDD	"	--	--	nd (70)	--	--	300	--	--	nd (100)	--	--	--
TetraCDF	"	--	--	nd (30)	--	--	nd (30)	--	--	nd (40)	--	--	--
PentaCDF	"	--	--	nd (30)	--	--	nd (40)	--	--	nd (40)	--	--	--
HexaCDF	"	--	--	nd (30)	--	--	nd (7)	--	--	nd (60)	--	--	--
HeptaCDF	"	--	--	nd (40)	--	--	nd (10)	--	--	nd (70)	--	--	--
OctaCDF	"	--	--	nd (60)	--	--	37	--	--	nd (100)	--	--	--

NOTES: "–" = not available.
"nd" = not detected.
"na" = not available.
Number in superscripts after concentration indicates the number of distinct isomers or compounds identified.
Values in parentheses for PCDDs and PCDFs are detection limits.

APPENDIX C

1989 Station Descriptions, Replicate Data and Statistical Analysis

Table C-1. Station locations and descriptions for 1989 study.

Station Number	Location	Distance from CDN. shore, m.	Water Depth, m.	Latitude (N)	Longitude (W)
1	Balsam Lake, at Rosedale	--	1.5	44°34'36"	78°47'28"
52	Point aux Pins Bay	500	4.5	46°29'49"	84°28'06"
124	Leigh Bay (northeast)	140	1.0	46°30'41"	84°24'45"
205	Leigh Bay (east)	210	3.0	46°30'32"	84°24'44"
123	Leigh Bay (east)	150	2.5	46°30'23"	84°24'46"
204	Leigh Bay (south)	50	4.5	46°30'13"	84°24'42"
203	Old Vessel Point	40	5.0	46°30'11"	84°24'30"
122	Old Vessel Point	15	6.5	46°30'09"	84°24'21"
202	Old Vessel Point	20	9.5	46°30'05"	84°24'08"
121	Old Vessel Point	40	6.0	46°30'11"	84°23'57"
201	2370 metres west of Algoma Slip entrance	50	5.5	46°30'14"	84°23'47"
200	2100 metres west of Algoma Slip entrance	80	5.0	46°30'19"	84°23'39"
199	1700 metres west of Algoma Slip entrance	60	8.5	46°30'23"	84°23'30"
198	1400 metres west of Algoma Slip entrance	60	6.0	46°30'29"	84°23'23"
197	1150 metres west of Algoma Slip entrance	50	7.0	46°30'36"	84°23'12"
196	900 metres west of Algoma Slip entrance	50	8.0	46°30'41"	84°23'05"
195	650 metres west of Algoma Slip entrance	70	7.0	46°30'46"	84°22'55"
127	500 metres west of Algoma Slip entrance	70	7.0	46°30'50"	84°22'50"

NOTES: Coordinates are in NAD27 Datum; distances from shore were determined by radar.

Table C-2. Sediment replicate physical characteristics, organic carbon and solvent extractables concentrations.
Concentration units as indicated.

Station Number	Field Sample Number	Visual (Field) Description	Very Coarse Sand 2000-1000 um %	Sand 1000-63 um %	Silt & Clay <63 um %	Moisture %	Field Density $g.cm^{-3}$	Residue, total loss on Ignition $g.kg^{-1}$	Organic Carbon, total $g.kg^{-1}$	Solvent Extractables $mg.kg^{-1}$
124	68202-S	silty sand; macrophytes	0.08	86.9	13.1	29	1.79	5.0	5.2	398
"	68203-S	"	0.08	87.6	12.3	28	"	3.0	5.8	254
204	68206-R	organic ooze; macrophytes	14.0	54.7	31.2	53	1.34	50	28	848
"	68207-R	"	11.1	53.9	35.0	52	"	53	28	295
"	68208-R	"	14.3	55.1	30.6	52	"	57	29	349
199	68215-S	sandy ooze; quite oily	0.49	45.5	42.2	37	1.69	47	72	--
"	68216-S	"	1.22	39.6	38.8	40	"	45	71	251
195	68220-R	oily ooze; some fine sand; plant and wood fibres	0.33	70.9	28.8	43	1.42	76	120	1481
"	68221-R	"	0.71	72.9	26.4	44	"	67	110	312
"	68222-R	"	1.46	73.5	25.0	51	"	87	130	305

NOTE: "S" = split (same grab) sample.
"R" = replicate (discrete grab) sample.

Table C-3. Arsenic, cyanide and heavy metals concentrations in sediment replicates.

All concentrations in mg.kg^{-1} (ppm), dry weight.

Station Number	Sample Date	Field Sample Number	Arsenic	Cadmium	Chromium	Copper	Cyanide available	Cyanide free	Iron	Lead	Magnesium,	Manganese	Mercury	Nickel	Zinc
124	89/08/16	68202-S	1.30	0.14 <T	11	5.1	0.040 <T	0.010 <W	7200	6.0	1600	120	0.01 <W	5.3	27
"	"	68203-S	1.20	0.13 <T	11	5.4	0.040 <T	0.010 <W	7500	6.0	1700	130	0.01 <W	4.9	27
204	"	68206-R	3.10	0.68	30	26	0.020 <T	0.010 <W	15000	20	4000	220	0.03 <T	15	70
"	"	68207-R	3.50	0.79	32	28	0.040 <T	0.010 <W	18000	28	4700	280	0.04 <T	15	78
"	"	68208-R	4.00	0.70	30	27	0.010 <W	0.010 <W	16000	19	4200	260	0.02 <T	15	74
199	"	68215-S	40.0	1.40	72	32	2.200	0.010 <W	170000	160	5100	3500	--	41	1300
"	"	68216-S	39.0	1.20 <TE	74	31	1.600	0.010 <W	170000	150	5000	3400	0.09	43	1300
195	"	68220-R	8.10	0.38	32	30	0.880	0.010 <W	35000	43	4700	740	0.08	16	220
"	"	68221-R	8.10	0.62	33	29	0.580	0.010 <W	37000	42	4800	770	0.08	17	210
"	"	68222-R	9.60	0.38	31	30	1.100	0.010 <W	34000	46	4800	720	0.05 <T	16	220

NOTES: blank or "--" indicates that data is not available for this sample

"<T" = a measurable trace amount: interpret with caution

"<TE" = a measurable trace after extra dilution or concentration caution

"<W" = no measurable response (zero): less than reported value

"S" = split (same grab) sample

R" = replicate (discrete grab) sample

Table C-4. Polycyclic aromatic hydrocarbon concentrations in sediment replicates.

All concentrations in $mg.kg^{-1}$ (ppm), dry weight.

Station Number	Sample Date	Field Sample Number	Ace-naph-thene	Ace-naph-thylene	Anthra-cene	Benzo(a)-anthra-cene	Benzo(b)-fluoran-thene	Benzo(k)-fluoran-thene	Benzo-(g,h,i)-perylyne	Benzo(a)-pyrene	Chry-sene	Dibenzo-(a,h)an-thracene	Fluor-anthene	Fluor-ene	Indeno-(1,2,3-cd)pyrene	Naph-thalene	Phen-anthrene	Pyrene	Total PAHs
124	89/08/16	68202-S	0.04 <T	0.05 <W	0.01 <T	0.02 <T	0.06 <T	0.02 <T	0.04 <T	0.04 <T	0.02 <T	0.04 <T	0.03 <T	0.04 <T	0.04 <T	0.04 <T	0.07 <T	0.06 <T	0.57
"	"	68203-S	0.04 <T	0.05 <W	0.01 <T	0.02 <T	0.06 <T	0.02 <T	0.04 <T	0.04 <T	0.02 <T	0.04 <T	0.03 <T	0.04 <T	0.04 <T	0.04 <T	0.07 <T	0.06 <T	0.57
204	"	68206-R	0.04 <T	0.05 <W	0.04 <T	0.10 <T	0.15 <T	0.07 <T	0.04 <T	0.10 <T	0.14 <T	0.04 <T	0.26	0.04 <T	0.07 <T	0.20 <T	0.15 <T	0.20 <T	1.64
"	"	68207-R	0.04 <T	0.05 <W	0.04 <T	0.12 <T	0.17 <T	0.08 <T	0.07 <T	0.13 <T	0.16 <T	0.04 <T	0.28	0.04 <T	0.08 <T	0.10 <T	0.15 <T	0.22 <T	1.72
"	"	68208-R	0.04 <T	0.05 <W	0.02 <T	0.09 <T	0.15 <T	0.07 <T	0.06 <T	0.09 <T	0.13 <T	0.04 <T	0.21	0.04 <T	0.07 <T	0.10 <T	0.10 <T	0.16 <T	1.37
199	"	68215-S	0.04 <T	0.05 <W	0.21	0.75	1.14	0.40	0.46	0.84	0.78	0.15 <T	1.33	0.10 <T	0.63	0.18 <T	0.66 <T	1.25	8.92
"	"	68216-S	0.04 <T	0.05 <W	0.26	0.72	1.01	0.37	0.36 <T	0.72	0.81	0.10 <T	1.50	0.11 <T	0.48	0.16 <T	0.79	1.38	8.81
195	"	68220-R	0.71	0.36 <T	1.95	5.90	7.66	2.97	3.22	6.16	6.13	0.94	11.16	1.14	4.20	2.42	7.65	8.56	71.13
"	"	68221-R	0.68	0.30 <T	1.81	6.37	8.25	3.26	3.46	6.75	6.59	1.10	10.58	1.08	4.70	2.03	6.73	8.26	71.95
"	"	68222-R	0.94	0.40 <T	2.53	6.64	8.30	3.17	3.52	6.74	6.36	1.15	13.56 >A	1.51	4.70	2.73	8.80	10.14 >A	81.19

NOTES: blank or "--" indicates that data is not available for this sample.

"<T" = a measurable trace amount: interpret with caution

"<W" = no measurable response (zero): less than reported value

">A" = approximate result: exceeded normal range limit

"S" = split (same grab) sample

"R" = replicate (discrete grab) sample

Table C-5. **Sediment parameter correlation coefficients.** Pearson Product-Moment analysis on log (x+1)-transformed concentration data; percentages were arc sin√x-transformed. Significant correlations at $p < 0.05$ are underlined. Pearson Product-Moment (n = 17).

	Fines	Moist	TOC	SOLEXT	As	Cd	Cr	Cu	CN	Fe	Pb	Mg	Mn	Hg	Ni	Zn	TPAHs	Ace	Anth	BaA	BbF
Fines	1.00	0.52	0.28	0.23	0.37	0.36	0.42	0.60	0.17	-0.17	0.35	0.07	0.22	0.33	0.48	0.39	0.24	0.04	0.09	0.16	0.19
Moist	0.52	1.00	0.71	0.15	0.51	0.64	0.37	0.86	0.30	0.12	0.61	0.16	0.08	0.60	0.65	0.63	0.40	0.41	0.38	0.41	0.42
TOC	0.28	0.71	1.00	0.07	0.81	0.51	0.61	0.88	0.67	0.33	0.87	0.47	0.49	0.77	0.75	0.82	0.78	0.72	0.73	0.76	0.77
SOLEXT	0.23	0.15	0.07	1.00	-0.23	-0.11	-0.34	0.04	-0.17	0.17	-0.09	-0.36	-0.33	-0.20	-0.26	-0.17	0.01	0.16	0.05	0.05	0.04
As	0.37	0.51	0.81	-0.23	1.00	0.56	0.75	0.78	0.84	0.18	0.97	0.45	0.64	0.84	0.92	0.96	0.72	0.56	0.62	0.66	0.69
Cd	0.36	0.64	0.51	-0.11	0.56	1.00	0.41	0.67	0.45	-0.03	0.61	0.15	0.19	0.52	0.64	0.60	0.13	-0.03	0.07	0.11	0.12
Cr	0.42	0.37	0.61	-0.34	0.75	0.41	1.00	0.71	0.50	0.05	0.66	0.85	0.93	0.56	0.77	0.66	0.64	0.28	0.44	0.50	0.52
Cu	0.60	0.86	0.88	0.04	0.78	0.67	0.71	1.00	0.57	0.20	0.83	0.47	0.48	0.75	0.85	0.82	0.68	0.54	0.59	0.63	0.65
CN	0.17	0.30	0.67	-0.17	0.84	0.45	0.50	0.57	1.00	0.45	0.83	0.26	0.46	0.67	0.76	0.86	0.66	0.60	0.62	0.65	0.66
Fe	-0.17	0.12	0.33	0.17	0.18	-0.03	0.05	0.20	0.45	1.00	0.19	0.10	0.08	0.01	0.16	0.26	0.38	0.56	0.47	0.42	0.39
Pb	0.35	0.61	0.87	-0.09	0.97	0.61	0.66	0.83	0.83	0.19	1.00	0.37	0.53	0.87	0.91	0.97	0.71	0.60	0.62	0.67	0.69
Mg	0.07	0.16	0.47	-0.36	0.45	0.15	0.85	0.47	0.26	0.10	0.37	1.00	0.87	0.32	0.44	0.33	0.59	0.26	0.47	0.48	0.47
Mn	0.22	0.08	0.49	-0.33	0.64	0.19	0.93	0.48	0.46	0.08	0.53	0.87	1.00	0.39	0.57	0.50	0.63	0.26	0.43	0.48	0.50
Hg	0.33	0.60	0.77	-0.20	0.84	0.52	0.56	0.75	0.67	0.01	0.87	0.32	0.39	1.00	0.80	0.87	0.72	0.61	0.66	0.72	0.75
Ni	0.48	0.65	0.75	-0.26	0.92	0.64	0.77	0.85	0.76	0.16	0.91	0.44	0.57	0.80	1.00	0.95	0.61	0.46	0.49	0.55	0.57
Zn	0.39	0.63	0.82	-0.17	0.96	0.60	0.66	0.82	0.86	0.26	0.97	0.33	0.50	0.87	0.95	1.00	0.71	0.62	0.63	0.68	0.70
TPAHs	0.24	0.40	0.78	0.01	0.72	0.13	0.64	0.68	0.66	0.38	0.71	0.59	0.63	0.72	0.61	0.71	1.00	0.88	0.95	0.98	0.98
Ace	0.04	0.41	0.72	0.16	0.56	-0.03	0.28	0.54	0.60	0.56	0.60	0.26	0.26	0.61	0.46	0.62	0.88	1.00	0.94	0.93	0.93
Anth	0.09	0.38	0.73	0.05	0.62	0.07	0.44	0.59	0.62	0.47	0.62	0.47	0.43	0.66	0.49	0.63	0.95	0.94	1.00	0.99	0.98
BaA	0.16	0.41	0.76	0.05	0.66	0.11	0.50	0.63	0.65	0.42	0.67	0.48	0.48	0.72	0.55	0.68	0.98	0.93	0.99	1.00	1.00
BbF	0.19	0.42	0.77	0.04	0.69	0.12	0.52	0.65	0.66	0.39	0.69	0.47	0.50	0.75	0.57	0.70	0.98	0.93	0.98	1.00	1.00
BkF	0.16	0.41	0.75	0.06	0.64	0.11	0.48	0.63	0.64	0.41	0.65	0.46	0.46	0.72	0.53	0.66	0.97	0.93	0.99	1.00	1.00
BghiPer	0.16	0.42	0.76	0.08	0.66	0.07	0.46	0.62	0.65	0.41	0.67	0.42	0.44	0.72	0.54	0.68	0.97	0.95	0.98	1.00	1.00
BaP	0.18	0.41	0.76	0.05	0.67	0.09	0.51	0.63	0.64	0.39	0.67	0.47	0.49	0.73	0.55	0.68	0.98	0.93	0.98	1.00	1.00
Chry	0.17	0.41	0.76	0.05	0.67	0.12	0.52	0.64	0.65	0.42	0.67	0.49	0.50	0.72	0.55	0.68	0.98	0.92	0.99	1.00	1.00
DahAnth	0.11	0.43	0.75	0.10	0.61	0.08	0.36	0.59	0.65	0.45	0.65	0.33	0.33	0.72	0.51	0.66	0.93	0.97	0.97	0.98	0.98
Flan	0.17	0.40	0.77	0.03	0.68	0.13	0.55	0.65	0.66	0.43	0.68	0.53	0.54	0.71	0.57	0.68	0.99	0.92	0.99	1.00	0.99
Fluor	0.05	0.40	0.73	0.12	0.59	0.01	0.34	0.56	0.62	0.54	0.62	0.34	0.32	0.63	0.48	0.63	0.91	0.99	0.98	0.96	0.95
IPyr	0.17	0.42	0.77	0.07	0.67	0.08	0.47	0.63	0.66	0.41	0.68	0.42	0.45	0.74	0.55	0.69	0.97	0.95	0.98	0.99	1.00
Naph	0.08	0.43	0.74	0.13	0.62	-0.02	0.32	0.57	0.61	0.49	0.66	0.27	0.28	0.66	0.51	0.67	0.88	0.99	0.93	0.93	0.93
Phen	0.10	0.39	0.75	0.04	0.64	0.10	0.47	0.61	0.65	0.47	0.65	0.47	0.45	0.69	0.52	0.66	0.96	0.94	1.00	0.99	0.99
Pyr	0.17	0.41	0.77	0.02	0.69	0.13	0.54	0.65	0.66	0.42	0.69	0.52	0.53	0.73	0.57	0.70	0.99	0.92	0.99	1.00	1.00

Table C-5. continued

	BkF	BghiPer	BaP	Chry	DahAnth	Flan	Fluor	IPyr	Naph	Phen	Pyr
Fines	0.16	0.16	0.18	0.17	0.11	0.17	0.05	0.17	0.08	0.10	0.17
Moist	0.41	0.42	0.41	0.41	0.43	0.40	0.40	0.42	0.43	0.39	0.41
TOC	0.75	0.76	0.76	0.76	0.75	0.77	0.73	0.77	0.74	0.75	0.77
SOLEXT	0.06	0.08	0.05	0.05	0.10	0.03	0.12	0.07	0.13	0.04	0.02
As	0.64	0.66	0.67	0.67	0.61	0.68	0.59	0.67	0.62	0.64	0.69
Cd	0.11	0.07	0.09	0.12	0.08	0.13	0.01	0.08	-0.02	0.10	0.13
Cr	0.48	0.46	0.51	0.52	0.36	0.55	0.34	0.47	0.32	0.47	0.54
Cu	0.63	0.62	0.63	0.64	0.59	0.65	0.56	0.63	0.57	0.61	0.65
CN	0.64	0.65	0.64	0.65	0.65	0.66	0.62	0.66	0.61	0.65	0.66
Fe	0.41	0.41	0.39	0.42	0.45	0.43	0.54	0.41	0.49	0.47	0.42
Pb	0.65	0.67	0.67	0.67	0.65	0.68	0.62	0.68	0.66	0.65	0.69
Mg	0.46	0.42	0.47	0.49	0.33	0.53	0.34	0.42	0.27	0.47	0.52
Mn	0.46	0.44	0.49	0.50	0.33	0.54	0.32	0.45	0.28	0.45	0.53
Hg	0.72	0.72	0.73	0.72	0.72	0.71	0.63	0.74	0.66	0.69	0.73
Ni	0.53	0.54	0.55	0.55	0.51	0.57	0.48	0.55	0.51	0.52	0.57
Zn	0.66	0.68	0.68	0.68	0.66	0.68	0.63	0.69	0.67	0.66	0.70
TPAHs	0.97	0.97	0.98	0.98	0.93	0.99	0.91	0.97	0.88	0.96	0.99
Ace	0.93	0.95	0.93	0.92	0.97	0.92	0.99	0.95	0.99	0.94	0.92
Anth	0.99	0.98	0.98	0.99	0.97	0.99	0.98	0.98	0.93	1.00	0.99
BaA	1.00	1.00	1.00	1.00	0.98	1.00	0.96	0.99	0.93	0.99	1.00
BbF	1.00	1.00	1.00	1.00	0.98	0.99	0.95	1.00	0.93	0.99	1.00
BkF	1.00	0.99	1.00	1.00	0.98	0.99	0.96	0.99	0.92	0.99	1.00
BghiPer	0.99	1.00	1.00	0.99	0.99	0.99	0.97	1.00	0.95	0.99	0.99
BaP	1.00	1.00	1.00	1.00	0.98	0.99	0.96	1.00	0.93	0.99	1.00
Chry	1.00	0.99	1.00	1.00	0.98	1.00	0.96	0.99	0.92	0.99	1.00
DahAnth	0.98	0.99	0.98	0.98	1.00	0.96	0.98	0.99	0.96	0.98	0.97
Flan	0.99	0.99	0.99	1.00	0.96	1.00	0.95	0.99	0.91	0.99	1.00
Fluor	0.96	0.97	0.96	0.96	0.98	0.95	1.00	0.97	0.98	0.97	0.95
IPyr	0.99	1.00	1.00	0.99	0.99	0.99	0.97	1.00	0.95	0.98	0.99
Naph	0.92	0.95	0.93	0.92	0.96	0.91	0.98	0.95	1.00	0.93	0.92
Phen	0.99	0.99	0.99	0.99	0.98	0.99	0.97	0.98	0.93	1.00	0.99
Pyr	1.00	0.99	1.00	1.00	0.97	1.00	0.95	0.99	0.92	0.99	1.00

Table C-6. Arsenic, heavy metals concentrations and moisture and lipid content in caged mussel replicates.

All concentrations in mg.kg^{-1} (ppm), wet weight.

Station Number	Sample Date	Field Sample Number	Arsenic	Cadmium	Copper	Lead	Magnesium	Manganese	Mercury	Nickel	Zinc	Moisture %	Lipids %
1	89/08/15	62385	0.47	1.500	1.50	0.59	226	860	0.02 <T	0.300 <	32.0	83	0.22
"	"	62386	1.10	1.000	1.20	0.90	178	920	0.01 <W	0.400 <	31.0	83	0.40
"	"	62387	0.33	1.700	1.30	0.60 <	294	1800	0.01 <W	0.400 <	47.0	82	0.38
52	NA	--	--	--	--	--	--	--	--	--	--	--	--
124	NA	--	--	--	--	--	--	--	--	--	--	--	--
205	89/09/08	62388	0.21	0.210	1.40	0.70 <	247	1000	0.01 <W	0.500 <	33.0	83	0.32
"	"	62389	0.35	1.200	2.50	0.78	252	540	0.02 <T	0.500 <	27.0	85	0.29
"	"	62390	0.43	1.100	2.00	0.81	287	1200	0.01 <W	0.400 <	41.0	84	0.32
123	"	62391	0.51	0.820	2.20	1.30	161	280	0.01 <W	0.500 <	22.0	85	0.36
"	"	62392	0.67	0.300	2.00	0.69	153	300	0.01 <W	0.400 <	21.0	88	0.45
"	"	62393	0.65	0.900	2.60	0.83	235	820	0.01 <W	0.400 <	29.0	87	0.38
204	"	62394	0.40	0.510	1.30	0.71	155	330	0.02 <T	0.400 <	20.0	87	0.57
"	"	62395	0.47	0.850	1.80	0.70 <	229	460	0.02 <T	0.500 <	41.0	85	0.30
"	"	62396	0.32	0.380	1.20	0.76	178	650	0.01 <W	0.500 <	35.0	85	0.36
203	"	62397	0.71	0.520	1.60	0.60 <	261	770	0.03 <T	0.400 <	31.0	86	0.29
"	"	62398	0.36	0.630	2.00	0.64	153	95	0.03 <T	0.400 <	20.0	85	0.29
"	"	62399	0.41	1.300	2.80	0.60 <	280	1000	0.02 <T	0.400 <	43.0	84	0.42
122	"	68557	0.45	1.000	2.40	0.70 <	151	220	0.01 <W	0.500 <	22.0	85	0.43
"	"	68558	0.54	0.460	3.90	0.70 <	203	860	0.02 <T	0.500 <	27.0	84	0.43
"	"	68559	0.40	0.270	2.00	0.70 <	270	1200	0.01 <W	0.500 <	38.0	81	0.28
202	NA	--	--	--	--	--	--	--	--	--	--	--	--
121	89/09/08	68560	0.63	0.260	1.20	0.60 <	140	440	0.01 <W	0.400 <	19.0	82	0.50
"	"	68561	0.46	0.560	2.30	0.60 <	139	120	0.01 <W	0.400 <	18.0	83	0.43
"	"	68562	0.36	1.200	1.60	0.70 <	263	1500	0.01 <W	0.500 <	41.0	82	0.56
121-M	"	68563	0.55	0.900	1.60	0.70 <	303	1800	0.01 <W	0.500 <	36.0	84	0.38
"	"	68564	0.36	0.730	1.40	0.50 <	266	750	0.01 <W	0.300 <	31.0	86	0.40
"	"	68565	0.24	0.940	2.20	0.60 <	223	540	0.02 <T	0.400 <	33.0	82	0.31
201	"	68566	0.30	1.100	2.00	0.60 <	324	1800	0.01 <W	0.400 <	53.0	81	0.66
"	"	68567	0.44	0.970	1.90	0.60 <	161	410	0.01 <W	0.400 <	33.0	82	0.51
"	"	68568	0.65	0.720	1.90	0.60 <	232	920	0.01 <W	0.400 <	27.0	82	0.41
200	"	68569	0.30	0.500	1.20	0.70 <	222	1400	0.01 <W	0.500 <	39.0	83	0.31
"	"	68570	0.56	0.850	1.60	0.58 <	248	1400	0.01 <W	0.400 <	39.0	83	0.28
"	"	68571	0.21	0.320	1.10	0.70 <	222	1100	0.02 <T	0.500 <	42.0	84	0.31
199	NA	--	--			--	--	--	--	--	--	--	--
198	89/09/08	68572	0.38	1.100	1.10	1.10 <	226	650	0.01 <W	0.400 <	32.0	83	0.63
"	"	68573	0.53	0.550	2.60	1.10 <	213	290	0.01 <W	0.400 <	28.0	81	0.40
"	"	68574	0.30	0.480	1.20	0.57 <	240	910	0.02 <T	0.400 <	33.0	84	0.84

Table C-6. continued.
All concentrations in $mg.kg^{-1}$ (ppm), wet weight.

Station Number	Sample Date	Field Sample Number	Arsenic	Cadmium	Copper	Lead	Magnesium	Manganese	Mercury	Nickel	Zinc	Moisture %	Lipids %
197	89/09/08	68575	0.34	0.790	2.30	0.66	289	1200	0.01 <W	0.400 <	45.0	81	0.58
"	"	68576	0.68	0.510	1.40	0.70 <	148	53	0.01 <W	0.500 <	22.0	82	0.66
"	"	68577	0.35	1.000	2.10	0.60 <	240	1300	0.01 <W	0.400 <	48.0	81	0.48
197-M	"	68578	0.32	0.370	2.20	0.70 <	232	820	0.01 <W	0.500 <	31.0	81	0.47
"	"	68579	0.31	1.300	2.80	0.50	306	1400	0.01 <W	0.400 <	49.0	83	0.69
"	"	68580	0.30	0.660	2.20	0.60 <	314	1200	0.01 <W	0.400 <	44.0	82	0.64
196	"	68581	0.26	0.500	1.50	0.70 <	240	970	0.01 <W	0.500 <	35.0	83	0.60
"	"	68582	0.55	0.680	2.20	0.78	259	1300	0.20 <T	0.400 <	46.0	83	0.72
"	"	68583	0.38	0.830	1.90	0.50 <	243	1100	0.01 <W	0.400 <	32.0	83	0.54
195	"	68584	0.51	1.300	1.60	0.70 <	263	970	0.01 <W	0.500 <	46.0	81	0.42
"	"	68585	0.81	0.610	1.70	0.73	198	530	0.01 <W	0.300 <	28.0	84	0.55
"	"	68586	0.31	0.990	1.50	0.68	294	1200	0.01 <W	0.400 <	39.0	83	0.51
127	"	68587	0.46	0.600	1.80	0.70 <	210	960	0.01 <W	0.500 <	25.0	85	0.19
"	"	68588	0.40	0.850	1.90	0.80 <	302	1900	0.01 <W	0.500 <	58.0	85	0.46
"	"	68589	0.26	0.970	1.80	0.60 <	374	1900	0.03 <T	0.400 <	54.0	84	0.38
127-M	"	68590	0.34	1.100	2.10	0.60 <	440	1900	0.03 <T	0.390	63.0	83	0.51
"	"	68591	0.48	1.200	1.70	0.60 <	266	1600	0.01 <W	0.400 <	47.0	83	0.38
"	"	68592	0.40	1.600	2.80	0.60 <	350	1700	0.02 <T	0.520	44.0	85	0.38

NOTES: "--" indicates that data is not available for this parameter or sample
"M" = mid-depth exposure; all others on bottom
"NA" = not available; cages lost
"<T" = a measurable trace amount: interpret with caution
"<W" = no measurable response (zero): less than reported value
"<" = less than reported value

Table C-7. Polycyclic aromatic hydrocarbons concentrations in caged mussesl replicates.

All concentrations in $ug.kg^{-1}$ (ppb), wet weight.

Station Number	Sample Date	Field Sample Number	Ace-naph-thene	Ace-naph-thylene	Anthra-cene	Benzo(a)-anthra-cene	Benzo(b)-fluoran-thene	Benzo(k)-fluoran-thene	Benzo-(g,h,i)-perylyne	Benzo(a)-pyrene	Chry-sene	Dibenzo-(a,h)an-thracene	Fluor-anthene	Fluor-ene	Indeno-(1,2,3-cd)pyrene	Naph-thalene	Phen-anthrene	Pyrene	Total of 16 PAHs
1	89/08/15	62385	15 <T	5 <W	11 <T	5 <W	7 <W	14 <T	6 <W	8 <W	9 <T	7 <W	20 <T	22 <T	6 <W	59 <T	115 <T	15 <T	280
"	"	62386	13 <T	5 <W	11 <T	7 <T	7 <W	6 <W	6 <W	8 <W	10 <T	7 <W	21 <T	29 <T	6 <W	56 <T	118 <T	15 <T	280
"	"	62387	9 <T	5 <W	11 <T	5 <T	7 <W	10 <T	6 <W	8 <W	7 <T	7 <W	20 <T	28 <T	6 <W	47 <T	120 <T	14 <T	271
52	NA	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
124	NA	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
205	89/09/08	62388	11 <T	5 <W	8 <T	5 <W	7 <W	6 <W	6 <W	8 <W	9 <T	7 <W	21 <T	19 <T	6 <W	20 <T	84 <T	12 <T	184
"	"	62389	11 <T	5 <W	13 <T	5 <W	7 <W	6 <W	6 <W	8 <W	7 <T	7 <W	22 <T	27 <T	6 <W	25 <T	126 <T	24 <T	255
"	"	62390	8 <W	5 <W	9 <W	8 <T	7 <W	6 <W	6 <W	8 <W	9 <T	7 <W	19 <T	18 <T	6 <W	19 <W	83 <T	12 <T	168
123	"	62391	18 <T	5 <W	16 <T	5 <W	7 <W	6 <W	6 <W	8 <W	9 <T	7 <W	27 <T	35 <T	6 <W	26 <T	159	16 <T	306
"	"	62392	8 <W	5 <W	10 <T	8 <T	7 <W	21 <T	6 <W	8 <W	13 <T	7 <W	23 <T	21 <T	6 <W	23 <T	98 <T	14 <T	231
"	"	62393	18 <T	5 <W	16 <T	5 <W	7 <W	6 <W	6 <W	8 <W	12 <T	7 <W	28 <T	34 <T	19 <T	30 <T	154	17 <T	328
204	"	62394	13 <T	5 <W	14 <T	6 <T	7 <W	6 <W	6 <W	8 <W	10 <T	7 <W	26 <T	31 <T	27 <T	33 <T	144	16 <T	320
"	"	62395	20 <T	5 <W	13 <T	5 <W	7 <W	6 <W	6 <W	8 <W	8 <T	7 <W	28 <T	38 <T	6 <W	23 <T	157	17 <T	304
"	"	62396	10 <T	5 <W	9 <T	5 <W	7 <W	6 <W	6 <W	8 <W	6 <T	7 <W	18 <T	24 <T	6 <W	29 <T	97 <T	11 <T	204
203	"	62397	20 <T	5 <W	19 <T	10 <T	7 <W	6 <W	6 <W	8 <W	13 <T	7 <W	33 <T	37 <T	6 <W	34 <T	185	23 <T	374
"	"	62398	12 <T	5 <W	11 <T	5 <W	7 <W	11 <T	6 <W	8 <W	7 <T	7 <W	26 <T	23 <T	13 <T	22 <T	105	19 <T	249
"	"	62399	8 <W	5 <W	8 <T	5 <W	7 <W	6 <W	6 <W	8 <W	7 <T	7 <W	22 <T	17 <T	44 <T	18 <T	78 <T	14 <T	208
122	"	68557	14 <T	5 <W	11 <T	6 <T	7 <W	6 <W	6 <W	8 <W	9 <T	7 <W	25 <T	25 <T	6 <W	27 <T	106	18 <T	241
"	"	68558	15 <T	5 <W	11 <T	5 <W	7 <W	6 <W	6 <W	8 <W	7 <T	7 <W	27 <T	30 <T	6 <W	34 <T	123 <T	18 <T	271
"	"	68559	8 <W	5 <W	9 <W	5 <W	7 <W	6 <W	6 <W	8 <W	6 <W	7 <W	8 <T	16 <W	6 <W	22 <T	28 <T	8 <T	58
202	NA	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
121	89/09/08	68560	8 <W	5 <W	9 <W	5 <W	7 <W	6 <W	6 <W	8 <W	9 <T	7 <W	26 <T	22 <T	6 <W	40 <T	59 <T	20 <T	150
"	"	68561	8 <W	5 <W	9 <W	5 <T	7 <W	6 <W	6 <W	8 <W	9 <T	7 <W	16 <T	16 <W	35 <T	19 <T	24 <T	12 <T	136
"	"	68562	8 <W	5 <W	9 <W	8 <T	7 <W	6 <W	6 <W	8 <W	14 <T	7 <W	16 <T	16 <W	112 UIN	28 <T	34 <T	11 <T	127
121-M	"	68563	8 <W	5 <W	9 <W	5 <T	.7 <W	6 <W	6 <W	8 <W	11 <T	7 <W	17 <T	16 <W	56 UIN	19 <T	28 <T	12 <T	108
"	"	68564	8 <W	5 <W	9 <W	6 <T	7 <W	6 <W	6 <W	8 <W	9 <T	7 <W	16 <T	16 <W	53 <T	19 <T	31 <T	11 <T	161
"	"	68565	8 <W	5 <W	9 <W	5 <T	7 <W	6 <W	6 <W	8 <W	8 <T	7 <W	14 <T	16 <W	6 <W	18 <T	27 <T	10 <T	98
201	"	68566	8 <W	5 <W	9 <W	5 <W	7 <W	6 <W	6 <W	8 <W	8 <T	7 <W	25 <T	16 <W	6 <W	29 <T	44 <T	17 <T	139
"	"	68567	8 <W	5 <W	9 <W	5 <W	7 <W	6 <W	6 <W	8 <W	8 <T	7 <W	15 <T	16 <W	6 <W	28 <T	40 <T	11 <T	118
"	"	68568	8 <W	5 <W	9 <W	5 <W	7 <W	6 <W	6 <W	8 <W	6 <W	7 <W	14 <T	16 <W	6 <W	29 <T	39 <T	9 <T	107
200	"	68569	8 <W	5 <W	9 <W	5 <W	7 <W	6 <W	6 <W	8 <W	8 <T	7 <W	10 <W	16 <W	6 <W	21 <T	23 <T	8 <W	52
"	"	68570	8 <W	5 <W	9 <W	5 <W	7 <W	6 <W	6 <W	8 <W	6 <T	7 <W	13 <T	16 <W	6 <W	19 <W	18 <T	9 <T	46
"	"	68571	8 <W	5 <W	9 <W	5 <W	7 <W	6 <W	6 <W	8 <W	6 <T	7 <W	10 <W	16 <W	6 <W	19 <W	18 <T	8 <W	24
202	NA	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
198	89/09/08	68572	39 <T	5 <T	17 <T	20 <T	25 <T	6 <W	6 <W	8 <W	51 <T	7 <W	161	55 <T	6 <W	200	205	111	889
"	"	68573	29 <T	5 <W	13 <T	15 <T	22 <T	12 <T	6 <W	8 <W	27 <T	7 <W	82	38 <T	6 <W	161 <T	163	58	620
"	"	68574	48 <T	6 <T	16 <T	30 <T	35 <T	23 <T	6 <W	8 <W	63	7 <W	165	54 <T	6 <W	198	181	135	954

Table C-7. continued.

All concentrations in $ug.kg^{-1}$ (ppb), wet weight.

Station Number	Sample Date	Field Sample Number	Ace-naph-thene	Ace-naph-thylene	Anthra-cene	Benzo(a)-anthra-cene	Benzo(b)-fluoran-thene	Benzo(k)-fluoran-thene	Benzo-(g,h,i)-perylyne	Benzo(a)-pyrene	Chry-sene	Dibenzo-(a,h)an-thracene	Fluor-anthene	Fluor-ene	Indeno-(1,2,3-cd)pyrene	Naph-thalene	Phen-anthrene	Pyrene	Total of 16 PAHs
197	89/09/08	68575	47 <T	8 <T	20 <T	51 <T	86	6 <W	6 <W	8 <W	98	7 <W	237	66 <T	6 <W	239	236	188	1276
"	"	68576	42 <T	6 <T	21 <T	73	112	69 UIN	6 <W	32 <T	108	7 <W	218	61 <T	44 <T	190 <T	225	183	1315
"	"	68577	59 <T	8 <T	27 <T	47 <T	94	6 <W	6 <W	18 <T	85	7 <W	230	83 <T	6 <W	294	321	191	1457
197-M	"	68578	60 <T	8 <T	29 <T	33 <T	78	6 <W	6 <W	8 <W	82	7 <W	227	85 <T	6 <W	267	327	173	1369
	"	68579	47 <T	5 <W	23 <T	51 <T	74	6 <W	6 <W	8 <W	128	7 <W	381	72 <T	6 <W	203	285	271	1535
"	"	68580	52 <T	5 <W	24 <T	72 <T	87	6 <W	6 <W	22 <T	134	7 <W	319	66 <T	6 <W	217	246	248	1487
196	"	68581	201	21 <T	75 <T	114 UI	115 UIN	6 <W	6 <W	58 <T	153 UI	7 <W	353	260	6 <W	786	821	283	2858
"	"	68582	156	17 <T	58 <T	133	181 UIN	6 <W	6 <W	65 <T	163	7 <W	309	200	6 <W	584	641	246	2572
"	"	68583	166	17 <T	63 <T	61	95	6 <W	6 <W	24 <T	92	7 <W	297	223	6 <W	672	723	232	2665
195	"	68584	148	15 <T	52 <T	63	67 UIN	54 <T	6 <W	29 <T	76	7 <W	216	189	6 <W	567	615	165	2189
"	"	68585	173	15 <T	64 <T	33 <T	37 <T	6 <W	6 <W	8 <W	51 <T	7 <W	269	223	6 <W	638	737	200	2440
"	"	68586	150	14 <T	55 <T	57	83	6 <W	6 <W	8 <W	90	7 <W	310	198	6 <W	596	668	234	2455
127	"	68587	147	14 <T	53 <T	47 <T	39 <T	36 <T	6 <W	8 <W	57 <T	7 <W	176	199	6 <W	554	615	142	2079
"	"	68588	108	11 <T	36 <T	41 <T	60 <T	6 <W	6 <W	8 <W	69	7 <W	197	148 <T	6 <W	431	444	158	1703
"	"	68589	56 <T	7 <T	18 <T	58	59 UIN	44 <T	6 <W	29 <T	67	7 <W	137	75 <T	6 <W	265	202	114	1072
127-M	"	68590	65 <T	7 <T	15 <T	34 <T	28 <T	18 <T	6 <W	8 <W	55 <T	7 <W	125	79 <T	6 <W	307	207	101	1041
"	"	68591	56 <T	6 <T	16 <T	38 <T	56 <T	6 <W	6 <W	8 <W	59 <T	7 <W	124	70 <T	6 <W	272	191	97	985
"	"	68592	41 <T	5 <W	13 <T	31 <T	43 <T	6 <W	6 <W	8 <W	49 <T	7 <W	106	56 <T	6 <W	201	159	84	783

NOTES "-" indicates that data is not available for this parameter or sample

"M" after station number indicates mid-depth exposure; all others on bottom

"NA" = not available; cages lost

"<T" = a measurable trace amount: interpret with caution

"<W" = no measurable response (zero): less than reported value

"UIN" = unreliable: indeterminate interference (result not included in 'Total PAHs')

Table C-8. **Mussel contaminant correlation coefficients for Total PAHs and metals.** Pearson Product-Moment analysis on log (x+1)-transformed concentration data; percentages were arc sin√x-transformed. Significant correlations at $p < 0.05$ are underlined (n = 13).

	TPAHs	As	Cd	Cu	Pb	Mg	Mn	Hg	Nickel	Zn	Moist	Lipids
TPAHs	1.00	0.02	0.34	-0.11	0.08	0.51	0.36	0.42	-0.29	0.50	-0.22	0.50
As	0.02	1.00	0.18	0.38	0.37	-0.49	-0.52	-0.28	-0.49	-0.54	0.16	0.20
Cd	0.34	0.18	1.00	0.07	0.01	0.58	0.26	-0.18	-0.20	0.35	-0.27	0.16
Cu	-0.11	0.38	0.07	1.00	0.10	-0.07	-0.18	0.06	-0.15	-0.39	0.13	-0.12
Pb	0.08	0.37	0.01	0.10	1.00	-0.26	-0.55	-0.09	0.37	-0.43	0.63	-0.07
Mg	0.51	-0.49	0.58	-0.07	-0.26	1.00	0.81	0.25	-0.09	0.83	-0.23	-0.11
Mn	0.36	-0.52	0.26	-0.18	-0.55	0.81	1.00	0.20	-0.21	0.85	-0.42	-0.11
Hg	0.42	-0.28	-0.18	0.06	-0.09	0.25	0.20	1.00	-0.05	0.18	0.07	0.18
Nickel	-0.29	-0.49	-0.20	-0.15	0.37	-0.09	-0.21	-0.05	1.00	-0.07	0.37	-0.38
Zn	0.50	-0.54	0.35	-0.39	-0.43	0.83	0.85	0.18	-0.07	1.00	-0.35	-0.01
Moist	-0.22	0.16	-0.27	0.13	0.63	-0.23	-0.42	0.07	0.37	-0.35	1.00	-0.57
Lipids	0.50	0.20	0.16	-0.12	-0.07	-0.11	-0.11	0.18	-0.38	-0.01	-0.57	1.00

Table C-9. **Mussel contaminant correlation coefficients for PAH compounds and metals.** Pearson Product-Moment analysis on log (x+1)-transformed concentration data; percentages were arc sin√x-transformed. Significant correlations at $p < 0.05$ are underlined. Pearson Product-Moment (n = 13) .

	Acen	Acy	Anth	BaA	BbF	BkF	BaP	Chry	Flan	Fluor	IP	Naph	Phen	Pyr	TPAHs	As	Cd	Cu	Pb	Mg
Acen	1.00	0.99	0.99	0.91	0.85	0.59	0.80	0.87	0.93	1.00	-0.33	0.99	0.99	0.92	0.97	0.02	0.31	-0.13	0.08	0.52
Acy	0.99	1.00	0.97	0.95	0.90	0.62	0.83	0.92	0.96	0.98	-0.31	1.00	0.98	0.95	0.98	-0.03	0.32	-0.15	0.00	0.55
Anth	0.99	0.97	1.00	0.91	0.85	0.58	0.81	0.87	0.92	0.99	-0.26	0.97	1.00	0.91	0.96	0.08	0.29	-0.07	0.18	0.46
BaA	0.91	0.95	0.91	1.00	0.98	0.60	0.93	0.99	0.96	0.91	-0.18	0.94	0.91	0.97	0.95	-0.07	0.19	-0.08	-0.02	0.46
BbF	0.85	0.90	0.85	0.98	1.00	0.60	0.91	0.99	0.96	0.85	-0.11	0.88	0.85	0.97	0.92	-0.06	0.19	-0.07	-0.03	0.42
BkF	0.59	0.62	0.58	0.60	0.60	1.00	0.30	0.63	0.69	0.59	-0.01	0.64	0.61	0.70	0.73	0.05	0.35	-0.13	0.08	0.44
BaP	0.80	0.83	0.81	0.93	0.91	0.30	1.00	0.90	0.82	0.80	-0.15	0.80	0.79	0.83	0.79	-0.12	0.03	-0.01	-0.04	0.33
Chry	0.87	0.92	0.87	0.99	0.99	0.63	0.90	1.00	0.97	0.87	-0.13	0.91	0.87	0.98	0.94	-0.07	0.19	-0.10	-0.02	0.43
Flan	0.93	0.96	0.92	0.96	0.96	0.69	0.82	0.97	1.00	0.92	-0.19	0.96	0.93	1.00	0.98	0.01	0.32	-0.12	0.03	0.47
Fluor	1.00	0.98	0.99	0.91	0.85	0.59	0.80	0.87	0.92	1.00	-0.30	0.98	1.00	0.92	0.96	0.02	0.31	-0.11	0.11	0.51
IP	-0.33	-0.31	-0.26	-0.18	-0.11	-0.01	-0.15	-0.13	-0.19	-0.30	1.00	-0.31	-0.28	-0.18	-0.22	0.36	-0.06	0.05	-0.05	-0.50
Naph	0.99	1.00	0.97	0.94	0.88	0.64	0.80	0.91	0.96	0.98	-0.31	1.00	0.98	0.95	0.98	-0.01	0.34	-0.15	0.00	0.54
Phen	0.99	0.98	1.00	0.91	0.85	0.61	0.79	0.87	0.93	1.00	-0.28	0.98	1.00	0.92	0.97	0.06	0.33	-0.09	0.16	0.49
Pyr	0.92	0.95	0.91	0.97	0.97	0.70	0.83	0.98	1.00	0.92	-0.18	0.95	0.92	1.00	0.98	-0.01	0.31	-0.12	0.01	0.48
TPAHs	0.97	0.98	0.96	0.95	0.92	0.73	0.79	0.94	0.98	0.96	-0.22	0.98	0.97	0.98	1.00	0.02	0.34	-0.11	0.08	0.51
As	0.02	-0.03	0.08	-0.07	-0.06	0.05	-0.12	-0.07	0.01	0.02	0.36	-0.01	0.06	-0.01	0.02	1.00	0.18	0.38	0.37	-0.49
Cd	0.31	0.32	0.29	0.19	0.19	0.35	0.03	0.19	0.32	0.31	-0.06	0.34	0.33	0.31	0.34	0.18	1.00	0.07	0.01	0.58
Cu	-0.13	-0.15	-0.07	-0.08	-0.07	-0.13	-0.01	-0.10	-0.12	-0.11	0.05	-0.15	-0.09	-0.12	-0.11	0.38	0.07	1.00	0.10	0.07
Pb	0.08	0.00	0.18	-0.02	-0.03	0.08	-0.04	-0.02	0.03	0.11	-0.05	0.00	0.16	0.01	0.08	0.37	0.01	0.10	1.00	-0.26
Mg	0.52	0.55	0.46	0.46	0.42	0.44	0.33	0.43	0.47	0.51	-0.50	0.54	0.49	0.48	0.51	-0.49	0.58	-0.07	-0.26	1.00
Mn	0.41	0.48	0.31	0.43	0.40	0.26	0.39	0.38	0.36	0.38	-0.49	0.45	0.34	0.38	0.36	-0.52	0.26	-0.18	-0.55	0.81
Hg	0.50	0.48	0.54	0.58	0.52	-0.13	0.76	0.52	0.42	0.50	-0.09	0.45	0.49	0.42	0.42	-0.28	-0.18	0.06	-0.09	0.25
Nickel	-0.27	-0.30	-0.22	-0.29	-0.29	-0.24	-0.20	-0.31	-0.33	-0.23	-0.06	-0.32	-0.22	-0.32	-0.29	-0.49	-0.20	-0.15	0.37	-0.09
Zn	0.49	0.55	0.42	0.50	0.50	0.49	0.40	0.48	0.49	0.47	-0.40	0.53	0.45	0.51	0.50	-0.54	0.35	-0.39	-0.43	0.83
Moist	-0.15	-0.25	-0.06	-0.30	-0.38	-0.06	-0.24	-0.35	-0.35	-0.11	0.07	-0.25	-0.10	-0.36	-0.22	0.16	-0.27	0.13	0.63	-0.23
Lipids	0.41	0.46	0.39	0.55	0.59	0.24	0.51	0.61	0.60	0.39	0.03	0.48	0.41	0.59	0.50	0.20	0.16	-0.12	-0.07	-0.11

Table C-9. continued.

	Mn	Hg	Nickel	Zn	Moist	Lipids
Acen	0.41	0.50	-0.27	0.49	-0.15	0.41
Acy	0.48	0.48	-0.30	0.55	-0.25	0.46
Anth	0.31	0.54	-0.22	0.42	-0.06	0.39
BaA	0.43	0.58	-0.29	0.50	-0.30	0.55
BbF	0.40	0.52	-0.29	0.50	-0.38	0.59
BkF	0.26	-0.13	-0.24	0.49	-0.06	0.24
BaP	0.39	0.76	-0.20	0.40	-0.24	0.51
Chry	0.38	0.52	-0.31	0.48	-0.35	0.61
Flan	0.36	0.42	-0.33	0.49	-0.35	0.60
Fluor	0.38	0.50	-0.23	0.47	0.11	0.39
IP	-0.49	-0.09	-0.06	-0.40	0.07	0.03
Naph	0.45	0.45	-0.32	0.53	-0.25	0.48
Phen	0.34	0.49	-0.22	0.45	-0.10	0.41
Pyr	0.38	0.42	-0.32	0.51	-0.36	0.59
TPAHs	0.36	0.42	-0.29	0.50	-0.22	0.50
As	-0.52	-0.28	-0.49	-0.54	0.16	0.20
Cd	0.26	-0.18	-0.20	0.35	-0.27	0.16
Cu	-0.18	0.06	-0.15	-0.39	0.13	-0.12
Pb	-0.55	-0.09	0.37	-0.43	0.63	-0.07
Mg	0.81	0.25	-0.09	0.83	-0.23	-0.11
Mn	1.00	0.20	-0.21	0.85	-0.42	-0.11
Hg	0.20	1.00	-0.05	0.18	0.07	0.18
Nickel	-0.21	-0.05	1.00	-0.07	0.37	-0.38
Zn	0.85	0.18	-0.07	1.00	-0.35	-0.01
Moist	-0.42	0.07	0.37	-0.35	1.00	-0.57
Lipids	-0.11	0.18	-0.38	-0.01	-0.57	1.00

Table C-10. Mussel contaminant correlation coefficients for PAHs and metals, including mid-depth exposure data. Pearson Product-Moment analysis on log (x+1)-transformed concentration data; percentages were arc sin√x-transformed. Significant correlations at $p < 0.05$ are underlined. Pearson Product-Moment (n = 16) .

	Acen	Acy	Anth	BaA	BbF	BkF	BaP	Chry	Flan	Fluor	IP	Naph	Phen	Pyr	TPAHs	As	Cd	Cu	Pb	Mg
Acen	1.00	0.98	0.98	0.90	0.83	0.60	0.79	0.81	0.85	1.00	-0.39	0.99	0.99	0.86	0.95	0.03	0.22	-0.06	0.10	0.38
Acy	0.98	1.00	0.96	0.90	0.84	0.64	0.82	0.80	0.83	0.98	-0.33	0.98	0.97	0.84	0.93	0.03	0.18	-0.13	0.05	0.34
Anth	0.98	0.96	1.00	0.89	0.83	0.59	0.81	0.81	0.86	0.99	-0.35	0.95	1.00	0.86	0.94	0.08	0.13	-0.01	0.23	0.28
BaA	0.90	0.90	0.89	1.00	0.98	0.57	0.88	0.97	0.94	0.90	-0.28	0.93	0.90	0.95	0.95	-0.15	0.18	0.05	-0.03	0.41
BbF	0.83	0.84	0.83	0.98	1.00	0.57	0.85	0.99	0.95	0.82	-0.25	0.87	0.84	0.97	0.92	-0.16	0.16	0.08	-0.04	0.39
BkF	0.60	0.64	0.59	0.57	0.57	1.00	0.32	0.55	0.61	0.61	-0.14	0.64	0.62	0.62	0.70	0.11	0.17	-0.11	0.14	0.23
BaP	0.79	0.82	0.81	0.88	0.85	0.32	1.00	0.79	0.73	0.79	-0.17	0.77	0.79	0.74	0.74	-0.08	-0.09	-0.02	0.03	0.14
Chry	0.81	0.80	0.81	0.97	0.99	0.55	0.79	1.00	0.98	0.81	-0.28	0.85	0.82	0.98	0.93	-0.22	0.17	0.11	-0.04	0.42
Flan	0.85	0.83	0.86	0.94	0.95	0.61	0.73	0.98	1.00	0.85	-0.33	0.89	0.87	1.00	0.96	-0.15	0.21	0.09	0.01	0.42
Fluor	1.00	0.98	0.99	0.90	0.82	0.61	0.79	0.81	0.85	1.00	-0.38	0.98	0.99	0.85	0.95	0.04	0.20	-0.05	0.15	0.35
IP	-0.39	-0.33	-0.35	-0.28	-0.25	-0.14	-0.17	-0.28	-0.33	-0.38	1.00	-0.38	-0.37	-0.32	-0.35	0.21	-0.06	-0.12	-0.13	-0.30
Naph	0.99	0.98	0.95	0.93	0.87	0.64	0.77	0.85	0.89	0.98	-0.38	1.00	0.97	0.90	0.97	-0.02	0.29	-0.05	0.01	0.44
Phen	0.99	0.97	1.00	0.90	0.84	0.62	0.79	0.82	0.87	0.99	-0.37	0.97	1.00	0.88	0.96	0.05	0.17	-0.02	0.20	0.31
Pyr	0.86	0.84	0.86	0.95	0.97	0.62	0.74	0.98	1.00	0.85	-0.32	0.90	0.88	1.00	0.96	-0.16	0.21	0.08	-0.00	0.42
TPAHs	0.95	0.93	0.94	0.95	0.92	0.70	0.74	0.93	0.96	0.95	-0.35	0.97	0.96	0.96	1.00	-0.05	0.27	0.04	0.07	0.44
As	0.03	0.03	0.08	-0.15	-0.16	0.11	-0.08	-0.22	-0.15	0.04	0.21	-0.02	0.05	-0.16	-0.05	1.00	0.01	0.16	0.42	-0.52
Cd	0.22	0.18	0.13	0.18	0.16	0.17	-0.09	0.17	0.21	0.20	-0.06	0.29	0.17	0.21	0.27	0.01	1.00	0.19	-0.22	0.75
Cu	-0.06	-0.13	-0.01	0.05	0.08	-0.11	-0.02	0.11	0.09	-0.05	-0.12	-0.05	-0.02	0.08	0.04	0.16	0.19	1.00	0.01	0.16
Pb	0.10	0.05	0.23	-0.03	-0.04	0.14	0.03	-0.04	0.01	0.15	-0.13	0.01	0.20	-0.00	0.07	0.42	-0.22	0.01	1.00	-0.41
Mg	0.38	0.34	0.28	0.41	0.39	0.23	0.14	0.42	0.42	0.35	-0.30	0.44	0.31	0.42	0.44	-0.52	0.75	0.16	-0.41	1.00
Mn	0.35	0.37	0.22	0.42	0.39	0.16	0.25	0.39	0.35	0.31	-0.35	0.42	0.25	0.37	0.36	-0.53	0.52	0.02	-0.61	0.86
Hg	0.48	0.48	0.49	0.51	0.43	-0.11	0.72	0.38	0.28	0.48	-0.08	0.43	0.45	0.30	0.35	-0.17	-0.04	0.02	-0.08	0.19
Nickel	-0.19	-0.24	-0.18	-0.22	-0.22	-0.19	-0.20	-0.23	-0.26	-0.16	-0.18	-0.22	-0.18	-0.26	-0.21	-0.35	0.08	-0.07	0.28	0.08
Zn	0.44	0.43	0.34	0.50	0.51	0.37	0.26	0.51	0.49	0.41	-0.39	0.51	0.38	0.50	0.50	-0.53	0.57	-0.09	-0.47	0.87
Moist	-0.17	-0.24	-0.09	-0.35	-0.43	-0.06	-0.25	-0.42	-0.42	-0.13	0.13	-0.27	-0.14	-0.43	-0.28	0.23	-0.16	0.02	0.56	-0.21
Lipids	0.42	0.43	0.42	0.59	0.65	0.24	0.49	0.67	0.67	0.41	-0.15	0.49	0.44	0.66	0.56	0.06	0.06	0.03	-0.04	-0.04

Table C-10. continued.

	Mn	Hg	Nickel	Zn	Moist	Lipids
Acen	0.35	0.48	-0.19	0.44	-0.17	0.42
Acy	0.37	0.48	-0.24	0.43	-0.24	0.43
Anth	0.22	0.49	-0.18	0.34	-0.09	0.42
BaA	0.42	0.51	-0.22	0.50	-0.35	0.59
BbF	0.39	0.43	-0.22	0.51	-0.43	0.65
BkF	0.16	-0.11	-0.19	0.37	-0.06	0.24
BaP	0.25	0.72	-0.20	0.26	-0.25	0.49
Chry	0.39	0.38	-0.23	0.51	-0.42	0.67
Flan	0.35	0.28	-0.26	0.49	-0.42	0.67
Fluor	0.31	0.48	-0.16	0.41	-0.13	0.41
IP	-0.35	-0.08	-0.18	-0.39	0.13	-0.15
Naph	0.42	0.43	-0.22	0.51	-0.27	0.49
Phen	0.25	0.45	-0.18	0.38	-0.14	0.44
Pyr	0.37	0.30	-0.26	0.50	-0.43	0.66
TPAHs	0.36	0.35	-0.21	0.50	-0.28	0.56
As	-0.53	-0.17	-0.35	-0.53	0.23	0.06
Cd	0.52	-0.04	0.08	0.57	-0.16	0.06
Cu	0.02	0.02	-0.07	-0.09	0.02	0.03
Pb	-0.61	-0.08	0.28	-0.47	0.56	-0.04
Mg	0.86	0.19	0.08	0.87	-0.21	-0.04
Mn	1.00	0.19	-0.05	0.88	-0.37	-0.06
Hg	0.19	1.00	0.02	0.17	0.11	0.10
Nickel	-0.05	0.02	1.00	0.11	0.35	-0.34
Zn	0.88	0.17	0.11	1.00	-0.33	0.06
Moist	-0.37	0.11	0.35	-0.33	1.00	-0.61
Lipids	-0.06	0.10	-0.34	0.06	-0.61	1.00